TC 24-21

TACTICAL MULTICHANNEL RADIO COMMUNICATIONS TECHNIQUES

HEADQUARTERS, DEPARTMENT OF THE ARMY

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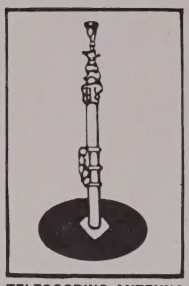
FIXED OPERATION WITH LONG-RANGE ANTENNAS

WARNING



TELESCOPING ANTENNA MAST

TYPICAL TOWER

EXTENDED-RANGE ANTENNA

DOUBLET ANTENNA

NEVER ERECT THESE LONG-RANGE ANTENNAS DIRECTLY UNDER POWER LINES.

IF YOU MUST ERECT THESE LONG-RANGE ANTENNAS NEAR POWER LINES, POWER LINE POLES OR TOWERS, OR BUILDINGS WITH OVERHEAD POWER LINE CONNECTIONS, NEVER PUT THE ANTENNA CLOSER THAN TWO TIMES THE ANTENNA HEIGHT FROM THE BASE OF THE POWER LINE, POLE, TOWER, OR BUILDINGS.

NEVER ATTEMPT TO ERECT ANY LONG-RANGE ANTENNA WITHOUT A FULL TEAM.

BEFORE ERECTING ANY LONG-RANGE ANTENNA, INSPECT ALL THE PARTS MAKING UP THE ANTENNA KIT. DO NOT ERECT THE ANTENNA IF ANY PARTS ARE MISSING OR DAMAGED.

DO AS MUCH OF THE ASSEMBLY WORK AS POSSIBLE ON THE GROUND.

WHEN ERECTING THE ANTENNA, ALLOW ONLY TEAM PERSONNEL IN THE ERECTION AREA.

MAKE SURE THAT THE AREA FOR THE ANCHORS IS FIRM. IF THE GROUND IS MARSHY OR SANDY, GET SPECIFIC INSTRUCTIONS FROM YOUR CREW CHIEF OR SUPERVISOR ON HOW TO REINFORCE THE ANCHORS.

WHEN SELECTING LOCATIONS FOR ANCHORS, AVOID TRAVELED AREAS AND ROADS. IF YOU CANNOT AVOID THESE AREAS, GET SPECIFIC INSTRUCTIONS FROM YOUR SUPERVISOR AS TO WHAT CLEARANCE YOUR GUY WIRES AND ROPES MUST HAVE OVER THE TRAVELED AREAS AND ROAD.

CLEARLY MARK ALL GUY WIRES AND ROPES WITH THE WARNING FLAGS OR SIGNS SUPPLIED BY YOUR UNIT. IN AN EMERGENCY, USE STRIPS OF WHITE CLOTH AS WARNING STREAMERS.

IF YOU SUSPECT THAT POWER LINES HAVE MADE ACCIDENTAL CONTACT WITH YOUR ANTENNA, STOP OPERATING, ROPE OFF THE ANTENNA AREA, AND NOTIFY YOUR SUPERIORS.

IF THE WEATHER IN YOUR AREA CAN CAUSE ICE TO FORM ON YOUR LONG-RANGE ANTENNA AND ITS GUY WIRES AND ROPES, ADD EXTRA GUYS TO SUPPORT THE SYSTEM. ROPE OFF THE AREA AND POST IT WITH WARNING SIGNS LIKE "BEWARE OF FALLING ICE."

DO NOT TRY TO ERECT ANY ANTENNA DURING AN ELECTRICAL STORM.

KEEP A SHARP EYE ON YOUR ANCHORS AND GUYS. CHECK THEM DAILY AND IMMEDIATELY BEFORE AND AFTER BAD WEATHER.

Unless otherwise stated, whenever the masculine gender is used, both men and women are included.

Training Circular
No 24-21

*TC 24-21
HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 3 October 1988

Tactical Multichannel Radio Communications Techniques

Preface

Purpose and Scope

This publication provides basic tactical multichannel radio communications techniques that will be useful to a wide range of signal corps personnel. It concentrates on LOS radio, tropo, and SATCOM that can provide from 4 to 144 channels of intelligence. It provides guidance in planning, installing, operating, and maintaining various multichannel communications systems.

User Information

The proponent of this publication is HQ TRADOC. Your comments on this publication are encouraged. Submit changes for improving this publication on DA Form 2028 (Recommended Changes to Publications and Blank Forms) and key them to pages and lines of text to which they apply. If DA Form 2028 is not available, a letter is acceptable. Provide reasons for your comments to ensure complete understanding and proper evaluation. Forward your comments to Commander, United States Army Signal Center and Fort Gordon, ATTN: ATZH-DTL, Fort Gordon, Georgia 30905-5075.

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Chapter 1
Multichannel Systems

Section I. Multichannel Operations

General

The commander of today's modern shoot, move, and communicate army must have a communications system he can rely on in order to maintain command and control of his troops. Today's mobile, flexible, and highly reliable tactical multichannel radio systems provide this type of communications.

Multichannel Transmission Media

The tactical multichannel systems use LOS radio, tropo, and satellite equipment as transmission media. A tactical multichannel system may vary from 4 to 144 channels of intelligence depending on the requirements of the commander and the equipment used.

A tactical multichannel system consists of two radio sets and associated multiplexing equipment (Figure 1-1). The distance by which the two radio terminals may be separated depends on the radio used. Although all radios are limited in range, relay stations may be used between the end terminals to extend the ranges (Figure 1-2).

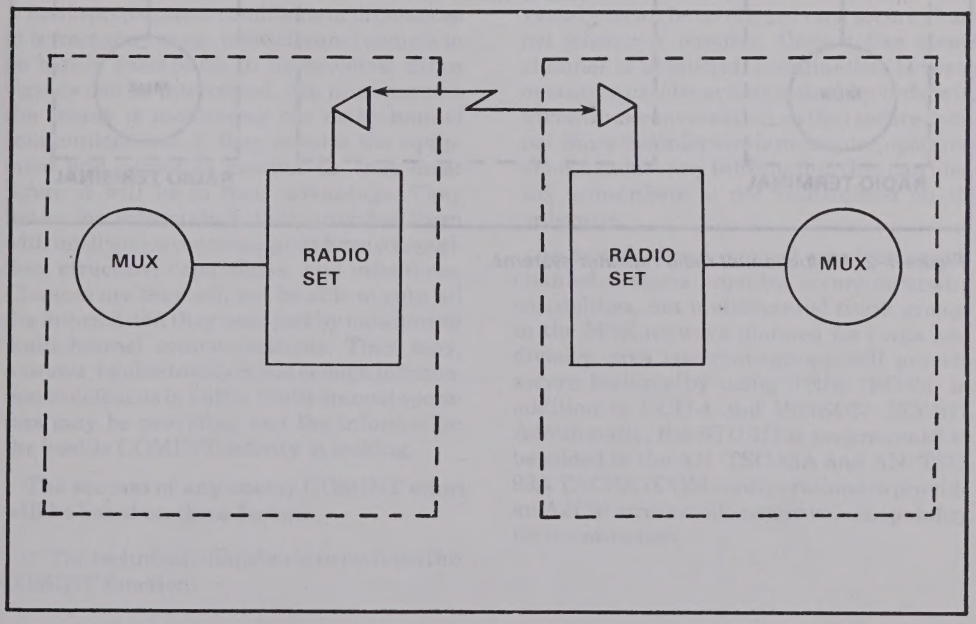

Figure 1-1. Multichannel radio terminal systems.

The tactical multichannel systems have high channel capacity and extended range. This gives the commander the capability of circuit alternate routing, dedicated (sole-user) circuits, and long-haul communications systems.

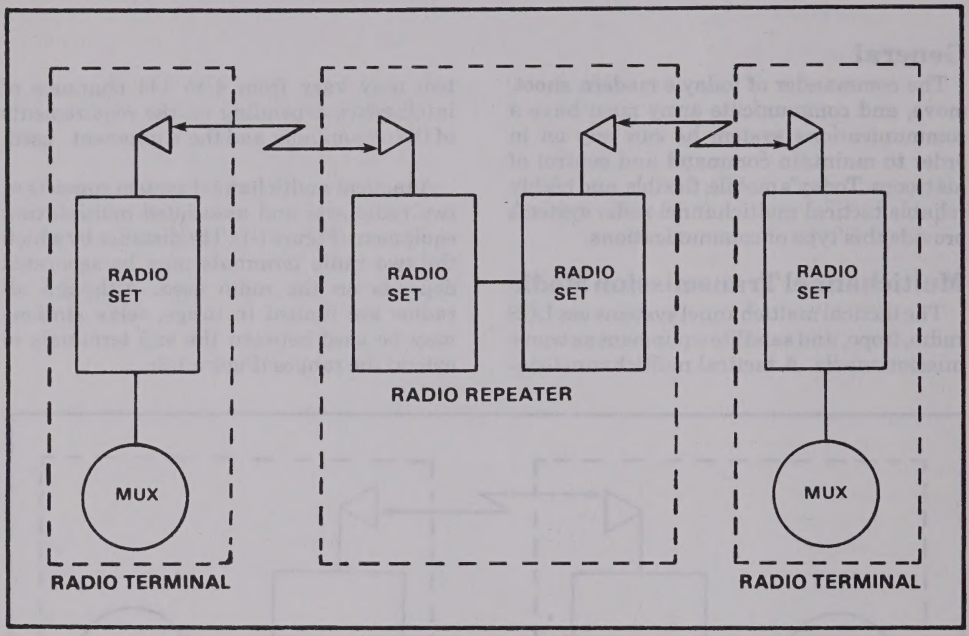

Figure 1-2. Multichannel radio repeater systems.

Multichannel Communications Security

Many personnel believe multichannel radio signals can be intercepted only—

- From positions forward of the directional transmitting antennas.
- Within or on the immediate fringes of the areas spanned by the signal beam.
- Forward of the radio transmission path.

Tests conducted over the last few years have produced evidence that completely destroys any basis for this belief. Nevertheless, multichannel communications operators continue to transmit classified (or sensitive) information, nonsecure, over the oderwire. This is a definite security violation and could result in disaster. FM 34-62 contains detailed information on COMSEC.

Radio propagation conditions or differences in terrain may cause multichannel signals to be highly susceptible to interception. Since signals can be intercepted, you must assume the enemy is monitoring our multichannel communications. If they commit the equipment and people to monitor us, they must figure it will be to their advantage. They listen for information that provides them with intelligence concerning our force composition, structure, capabilities, and intentions. Chances are they will not be able to gain all the information they need just by monitoring multichannel communications. They may, however, be able to collect just enough information to defeat us in battle. Multichannel operators may be providing just the information the hostile COMINT activity is seeking.

The success of any enemy COMINT effort will be based on three factors:

□ The technical competence to perform the COMINT function.

□ The availability of operational resources to perform the COMINT function.

□ The opportunity to use these resources.

The enemy controls the first two factors but you control the last. Fortunately, multichannel operators have at their disposal everything necessary to deny success to enemy COMINT efforts.

The assigned KG-27 bulk encryption device secures your customer's communications. The equipment operator's manual and your unit or site SOP contain information regarding those cryptographic and physical security measures that the operator must apply. This device does not secure the orderwire. Strict compliance with transmission security measures will seriously degrade hostile COMINT activity efforts. Operator-to-operator conversation can be conducted on a secure channel whenever possible. Once a free secure channel is identified, coordination between operators can be accomplished by orderwire to continue conversation on that secure channel. Since the orderwire is not secure, operators should ensure any information that can identify subscribers is not transmitted on the orderwire.

As noted above, not all previous multichannel systems provided secure orderwire capabilities, but multichannel trunk groups in the MSE network planned for corps and division area communications will provide secure features by using TEDs (KG-94) in addition to OCU-4 and VINSON (KY-57). Additionally, the STU-III is programmed to be added to the AN/TSC-85A and AN/TSC-93A TACSATCOM configurations to provide an AJCM stress mode secure voice capability for coordination.

Section II. Multichannel Radio Systems

Multichannel Radio Sets

The radio sets used in multichannel systems are designed specifically for use in multichannel systems and are not normally used without multiplex equipment. The multiplexing equipment gives the system the multichannel capability.

Some multichannel radio sets require two antennas, one to transmit and another to receive. However, radio sets equipped with a duplexer or diplexer use the same antenna to transmit and to receive (Figure 1-3).

Multichannel Frequency Spectrum Use

The multichannel radio sets use only a selected portion of the frequency spectrum. The lowest frequency used in the multichannel systems is 30 MHz in the VHF range. The highest frequency used is 15 GHz in the SHF range. Each radio set operates within a specific band of frequencies. Some bands may overlap or parallel those of other radio sets.

The VHF/UHF bands cover frequencies from 30 to 300 MHz and 300 to 3000 MHz. Radio systems using these bands normally require an LOS path between the transmitting and receiving antennas (Figure 1-4A). Tactical multichannel systems using these frequency bands are normally limited to 40 to 80 kilometers (25 to 50 miles) in a single link.

A portion of the SHF band (4.4 to 5.0 GHz) is used by radio sets using tropo propagation. These radio sets do not require an LOS path between the transmitting and receiving antennas. The radio waves of these sets are reflected off the troposphere, 10 to 16 kilometers (6 to 10

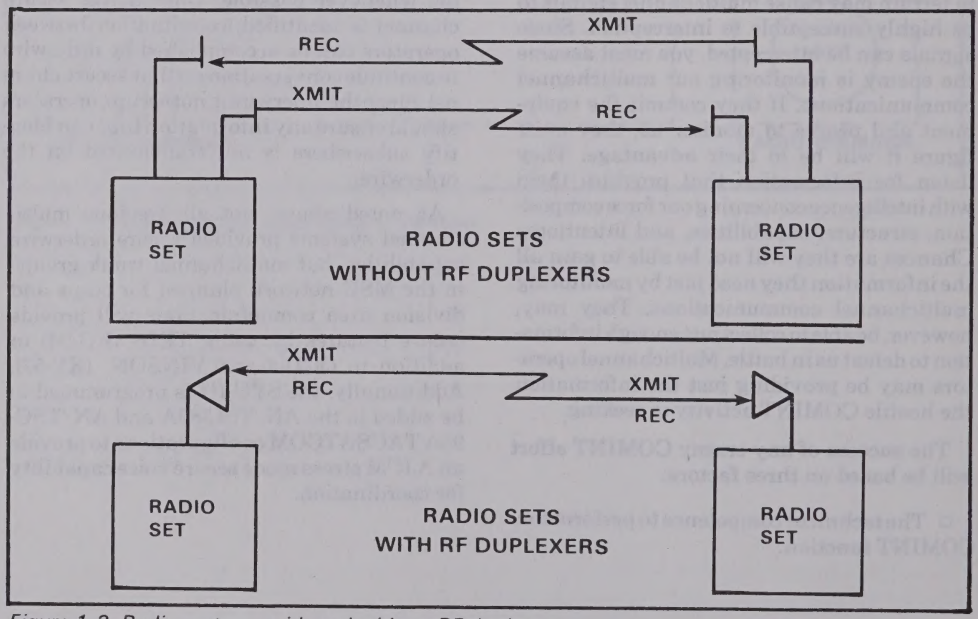

Figure 1-3. Radio systems with and without RF duplexers.

miles) above the earth and scattered back to earth beyond the horizon (Figure 1-4B). These systems are normally limited to 160 to 480 kilometers (100 to 300 miles) in a single link.

TACSAT multichannel systems use another portion (7.25 to 8.4 GHz) of the SHF band. These radio sets do not require an LOS path between the ground terminal transmitting and receiving antennas. They use an orbital satellite as a relay station (Figure 1-4C). The TACSAT systems normally provide reliable communications over terrestrial distances up to 16,000 kilometers (10,000 miles).

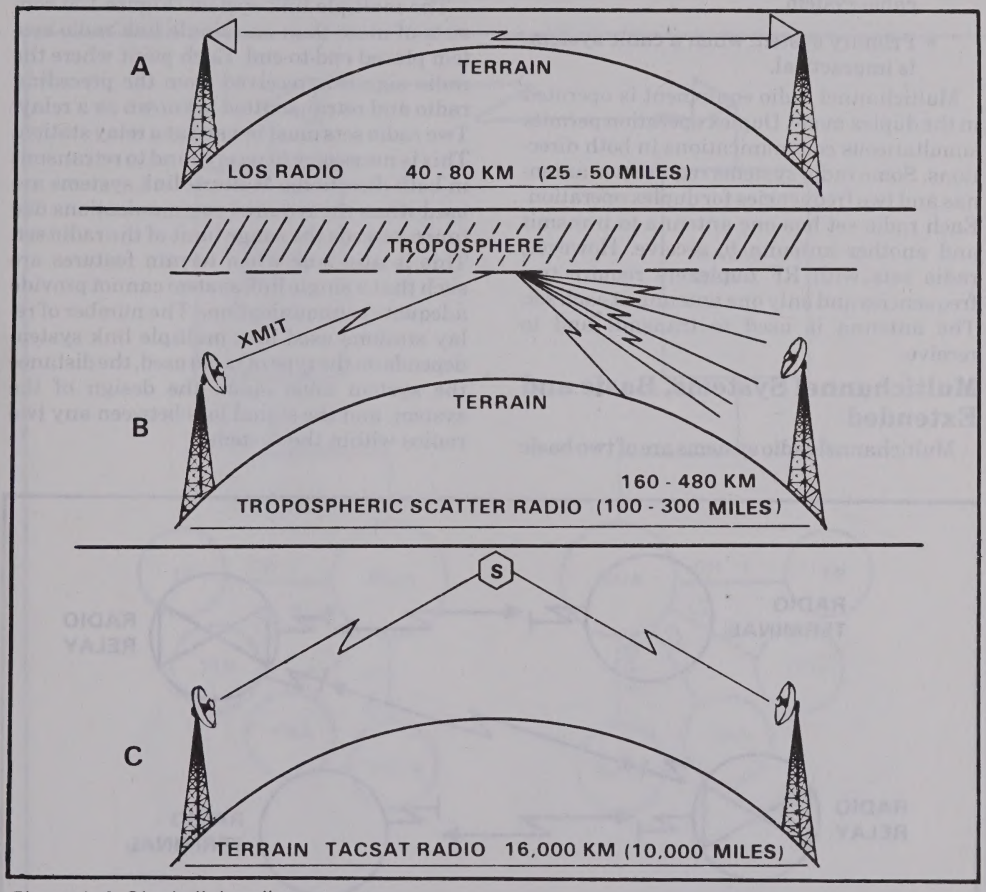

Figure 1-4. Single link radio systems.

Multichannel Systems Use and Operation

A multichannel radio system may be used as a:

- Primary communications facility.
- Supplement or extension of an existing cable system.
- Primary system when a cable system is impractical.

Multichannel radio equipment is operated in the duplex mode. Duplex operation permits simultaneous communications in both directions. Some radio systems require two antennas and two frequencies for duplex operation. Each radio set has one antenna to transmit and another antenna to receive. However, radio sets with RF duplexers require two frequencies and only one antenna at each set. The antenna is used to transmit and to receive.

Multichannel Systems, Basic and Extended

Multichannel radio systems are of two basic types: the single link and the multiple link systems.

The single link radio system has two terminals, one at each end of the system. The type of radio, the terrain, the antenna, and the transmitter power governs the distance between single link radio terminals.

The multiple link system (Figure 1-5) consists of more than one single link radio system placed end-to-end. Each point where the radio signal is received from the preceding radio and retransmitted is known as a relay. Two radio sets must be used at a relay station. This is necessary to receive and to retransmit in both directions. Multiple link systems are used when the required communications distance exceeds the range limit of the radio set. This is also true when terrain features are such that a single link system cannot provide adequate communications.The number of relay stations used in a multiple link system depends on the type of radio used, the distance the system must span, the design of the system, and the signal loss between any two radios within the system.

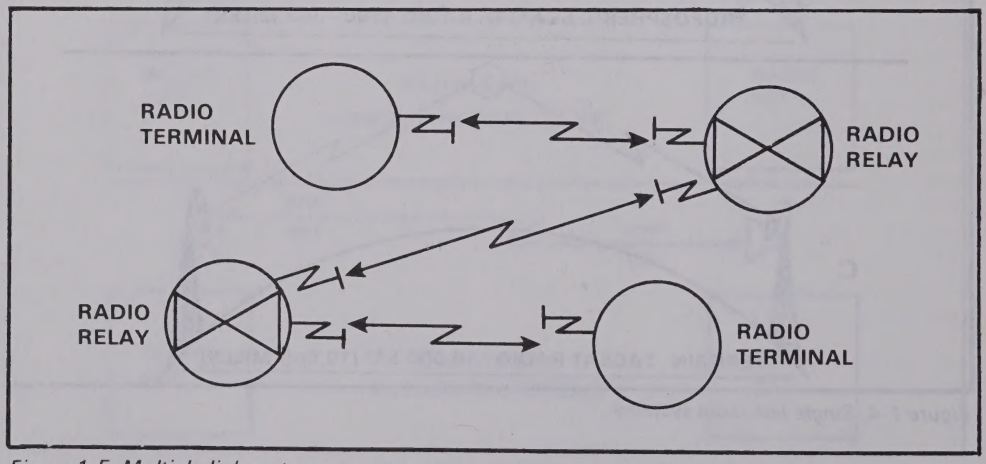

Figure 1-5. Multiple link system.

Section III. Multiplexing Systems

Multiplexing Terminals

Multichannel communications are made possible by using multiplexing equipment. At a mux terminal, from 4 to 144 channels (depending on the mux system used) of intelligence enter the multiplex equipment. These signals are combined into a single frequency, called the carrier frequency, through a process called modulation. Then the carrier frequency is transmitted over the radio system to a distant terminal. At the distant terminal the carrier frequency is demodulated by the radio. The channels are then demultiplexed by the multiplexer, thus retrieving the original 4 to 144 channels which are routed to the proper addresses (Figure 1-6).

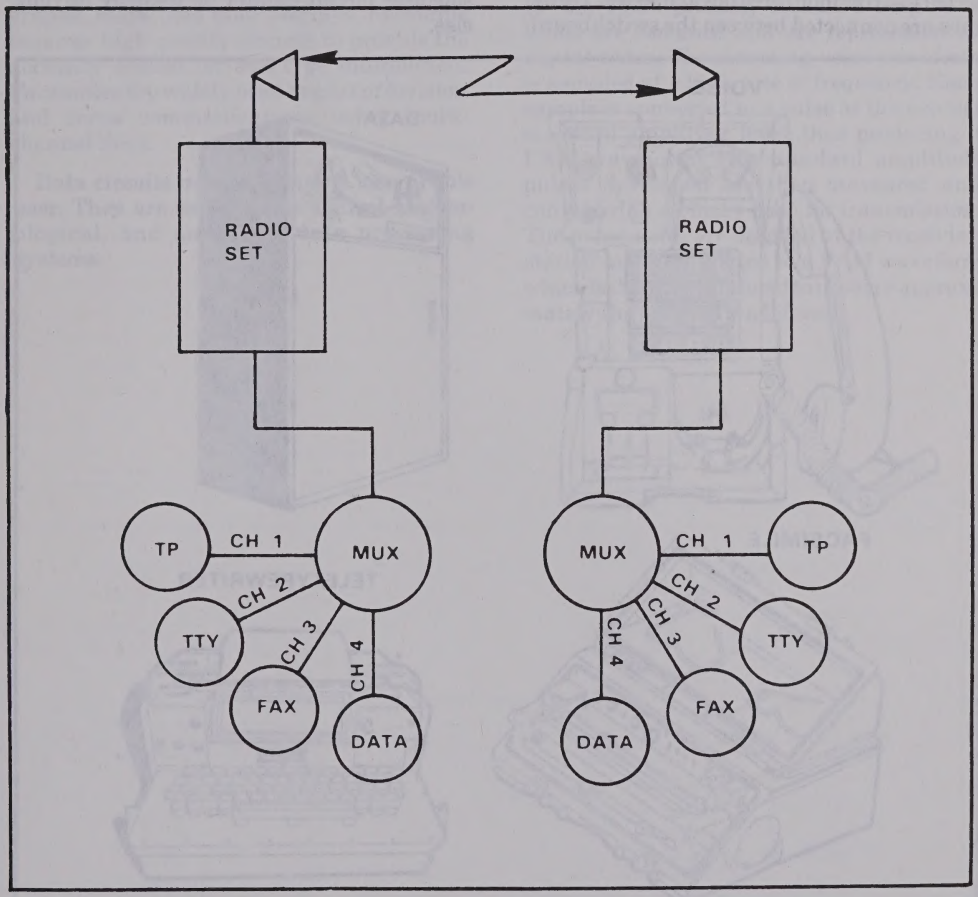

Figure 1-6. Radio multiplex system.

Multichannel Systems Communications Facilities

Multichannel systems are designed to meet requirements for the following communications facilities (Figure 1-7).

Direct voice communication between two or more individuals is a service available to the user. Voice communications are of two types: common user and sole user.

□ The common-user voice circuit is connected to a common (area) switchboard. Trunk lines are connected between the switchboard and a mux terminal to provide long distance communications from one switchboard to another. Any trunk circuit is available to any user.

□ The sole-user lines provide direct point-to-point voice communications without the use of a switchboard. They are connected directly to a channel of the mux terminal. The sole-user circuit cannot be used by anyone else.

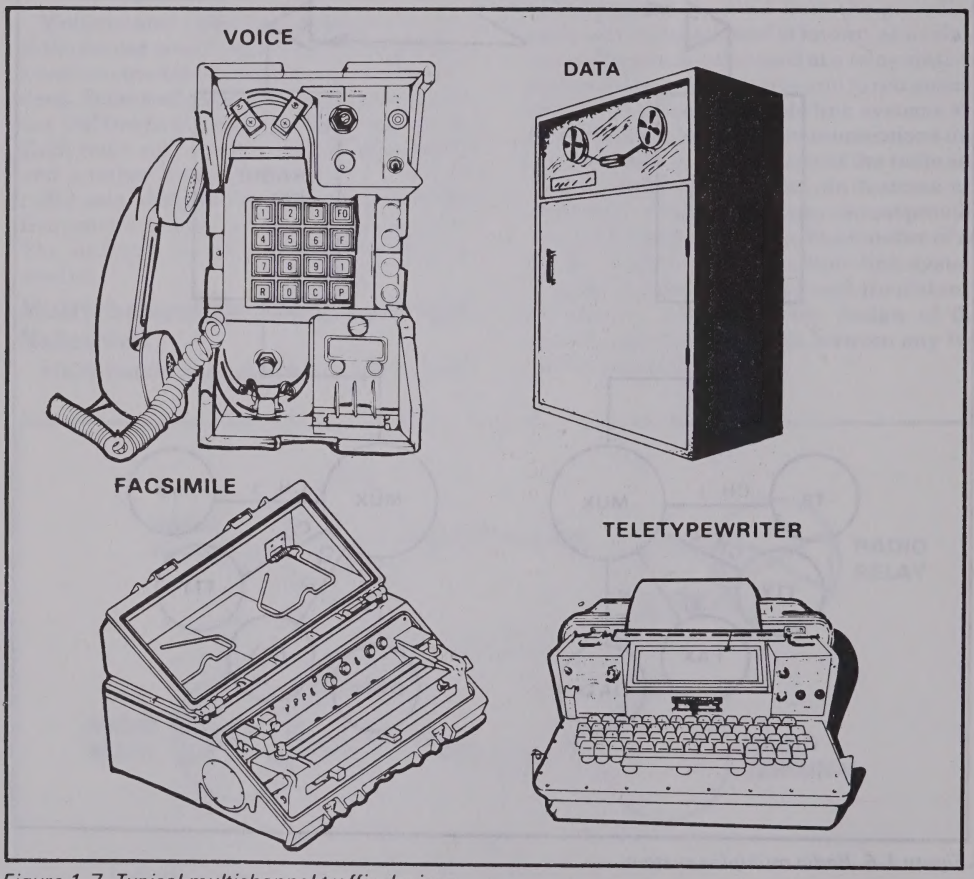

Figure 1-7. Typical multichannel traffic devices.

The teletypewriter is a means of rapidly transmitting typed messages over multichannel circuits. They normally use sole-user circuits and originate and terminate at a telecommunications center. Teletypewriter traffic provides a record copy of messages transmitted and received.

Facsimile is a method of transmitting messages and graphic material such as photographs, maps, and map overlays. Facsimile requires high quality circuits to provide the accuracy needed for this type information. Facsimiles are widely used as part of division and corps communications using multichannel lines.

Data circuits may be common user or sole user. They are used for fire control, meteorological, and automatic data processing systems.

Multiplexing

In TDM, each channel is assigned a specific but different time sequence with all the other channels that are being multiplexed (Figure 1-8). Each channel shares the transmission time and is intermittently transmitted. The amount of time each channel occupies the transmission line is very short; therefore, each channel must be sampled at a high rate of speed. PCM is used with TDM (Figure 1-9). In the PCM process, standard amplitude levels are assigned and are represented by digital codes. The incoming voice waveform is sampled at a high rate of frequency. Each sample is converted to a pulse at the nearest standard amplitude level, thus producing a PAM waveform. The standard amplitude pulses developed are then measured and converted to a binary code for transmission. The pulse codes are decoded at the receiving station and reconverted to a PAM waveform which is then demodulated to produce approximately the original waveform.

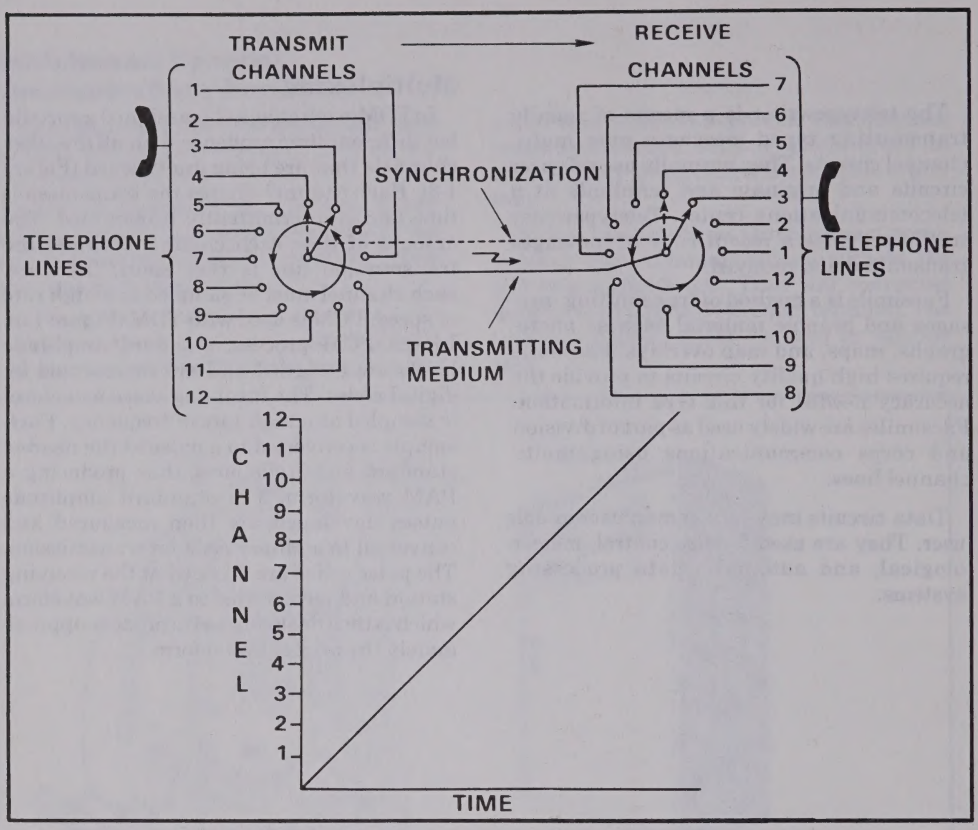

Figure 1-8. Simplified 12-channel TDM system.

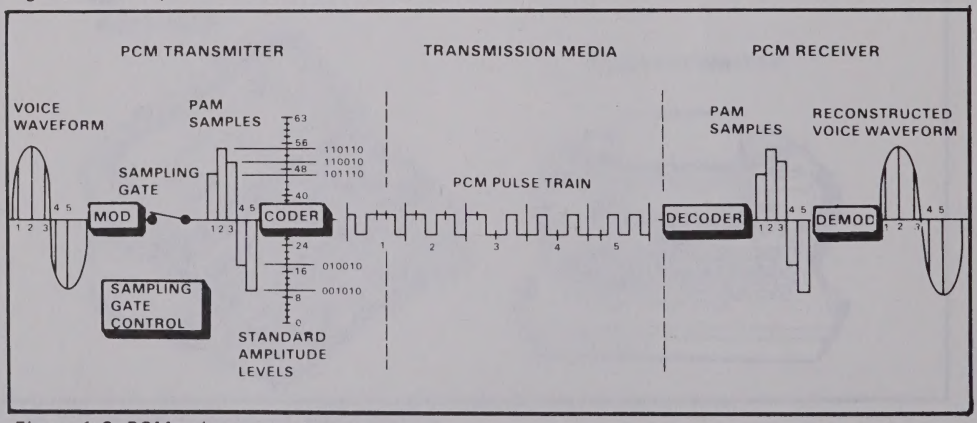

Figure 1-9. PCM voice transmission.

Section IV. Combined Radio and Multiplexing Systems

Types of Multiplexers

The multiplexers used with the multichannel radios permit the 4 to 144 channels of intelligence to be transmitted over one radio. A radio transmission interface unit must be used between the multiplexer and radio in the TDM systems (Figure 1-10).

The combined radio multichannel system uses both radio and cable as a means of transmission (Figure 1-11). This type system has an established cable system connected to an established radio system. For example, instead of running cable around a large lake, a radio system provides the link in the system to span the lake. This is called radio-to-cable conversion.

A drop and insert system is a relay station and a terminating point combined. Some circuits are relayed directly on to a distant multichannel terminal, some channels are dropped from the system, and other circuits are inserted into the system. Twelve channels may be dropped and twelve channels reinserted (Figure 1-12).

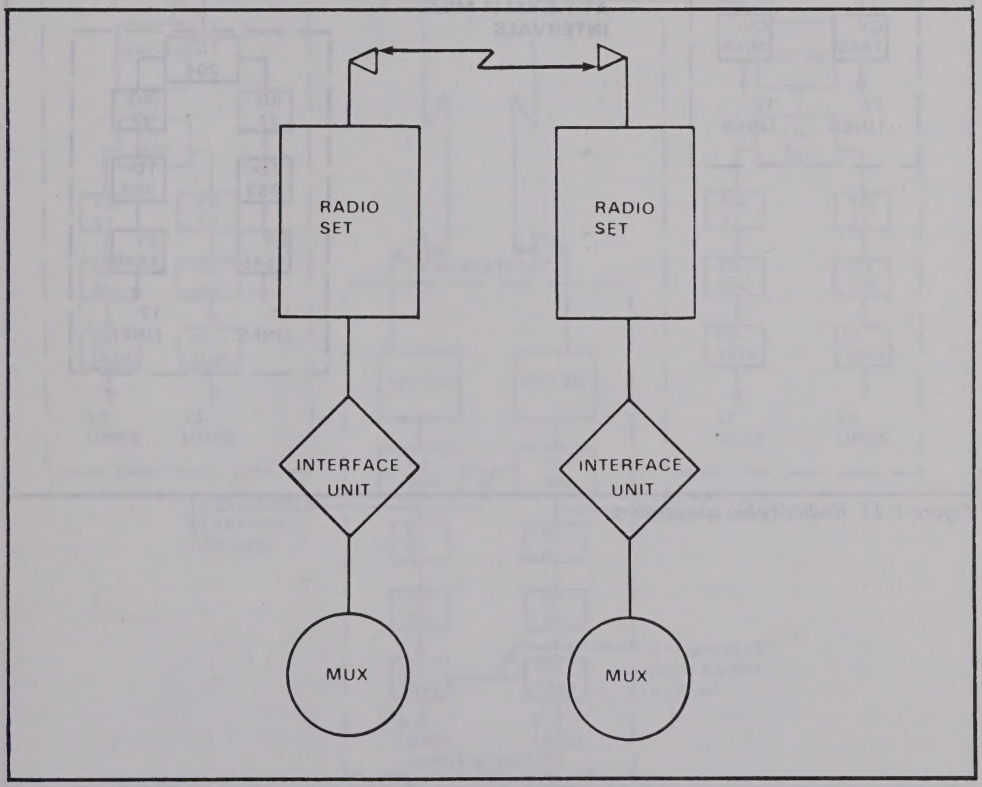

Figure 1-10. TDM radio/multiplex system.

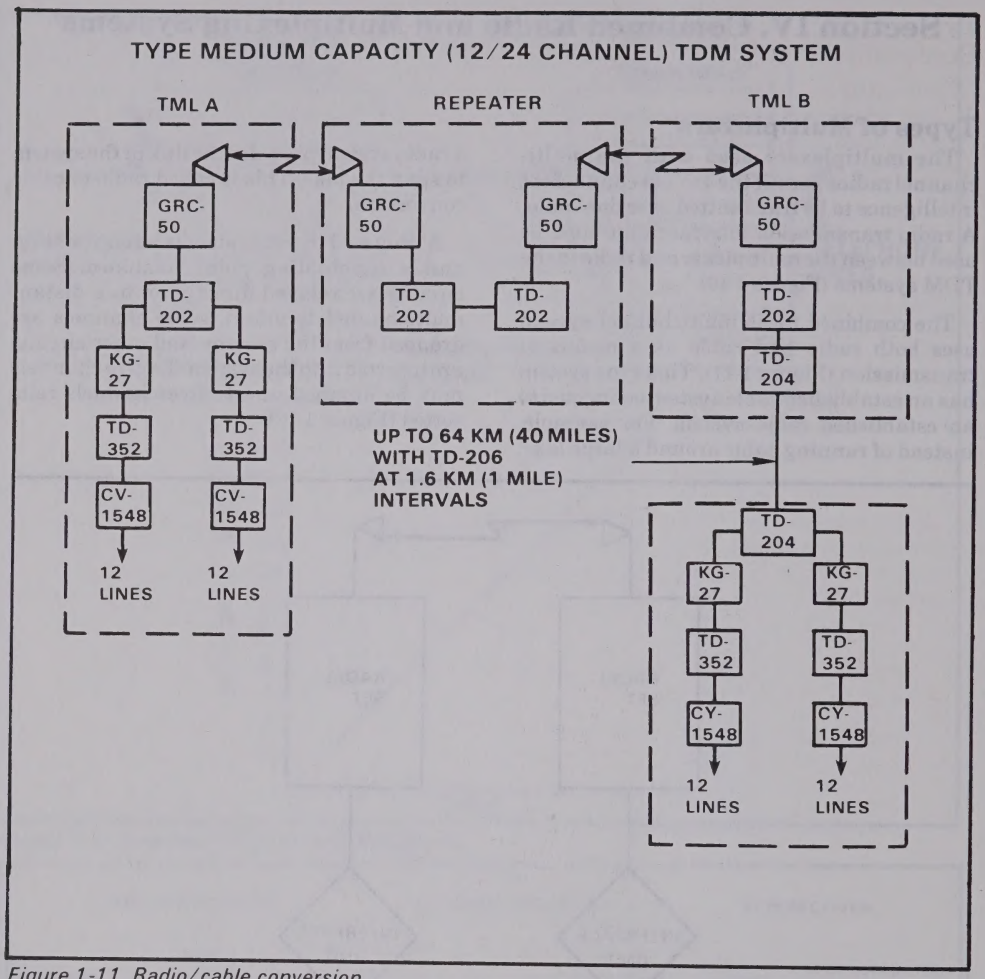

Figure 1-11. Radio/cable conversion.

Types of Tactical Multichannel Communications Systems

Three different types of tactical multichannel systems are used in the ATACS. ATACS uses DGM mux equipment, the newer types of radio, and TDM mux equipment.

The low capacity system (4, 6, or 12 channels) consists of radio and mux equipment mounted on trailers or in vehicle-mounted shelters to facilitate movement. These systems support division.

The medium capacity system (12 or 24 channels) consists of radio and mux equipment in vehicle-mounted shelters to facilitate movement. These systems support corps and above.

The high capacity system (48 or 144 channels) consists of radio and mux equipment in vehicle-mounted shelters to facilitate movement. These systems support echelons above corps.

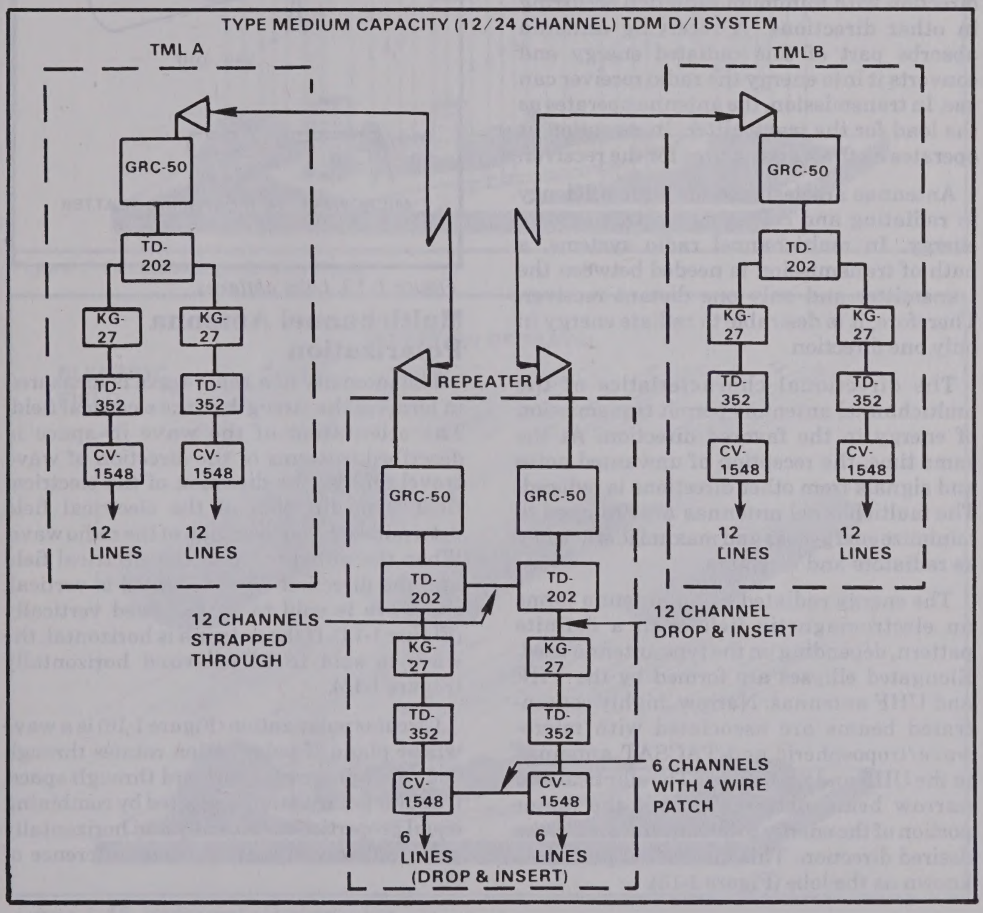

Figure 1-12. Typical multichannel D/I applications.

Section V. Multichannel Radio Antennas

Multichannel Antenna Operation

The RF energy in multichannel systems is generated by the radio transmitter. It is then fed through a transmission line to a transmitting antenna. The antenna radiates the RF energy into space at approximately the speed of light. Normally, the antenna also directionalizes the RF energy so that maximum radiation occurs in a specific direction with minimum radiation occurring in other directions. A receiving antenna absorbs part of this radiated energy and converts it into energy the radio receiver can use. In transmission, the antenna operates as the load for the transmitter. In reception, it operates as the signal source for the receiver.

Antennas are designed for high efficiency in radiating and collecting electromagnetic energy. In multichannel radio systems, a path of transmission is needed between the transmitter and only one distant receiver. Therefore, it is desirable to radiate energy in only one direction.

The directional characteristics of the multichannel antennas permit transmission of energy in the favored direction. At the same time, the reception of unwanted noise and signals from other directions is reduced. The multichannel antennas are designed to minimize energy loss and maximize efficiency as radiators and receptors.

The energy radiated by an antenna forms an electromagnetic field with a definite pattern, depending on the type antenna used. Elongated ellipses are formed by the VHF and UHF antennas. Narrow, highly concentrated beams are associated with microwave/tropospheric and TACSAT antennas in the UHF and SHF range. The elliptical and narrow beam patterns permit the major portion of the energy to be concentrated in the desired direction. This directional pattern is known as the lobe (Figure 1-13).

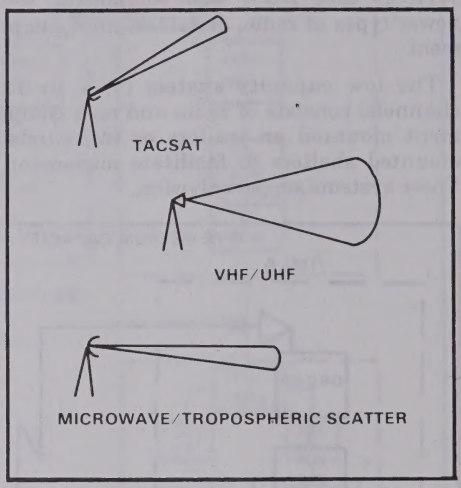

Figure 1-13. Lobe patterns.

Multichannel Antenna Polarization

The intensity of a radio wave is measured in terms of the strength of the electrical field. The orientation of the wave in space is described in terms of the direction of wave travel and by the direction of the electrical field. The direction of the electrical field determines the polarization of the radio wave. When the antenna emits the electrical field and the direction of wave travel is vertical, the wave is said to be polarized vertically (Figure 1-14). If the antenna is horizontal, the wave is said to be polarized horizontally (Figure 1-15).

Circular polarization (Figure 1-16) is a wave whose plane of polarization rotates through 360° as it progresses forward through space. Circular polarization is created by combining equal properties of vertically and horizontally polarized waves, with a phase difference of 90°.

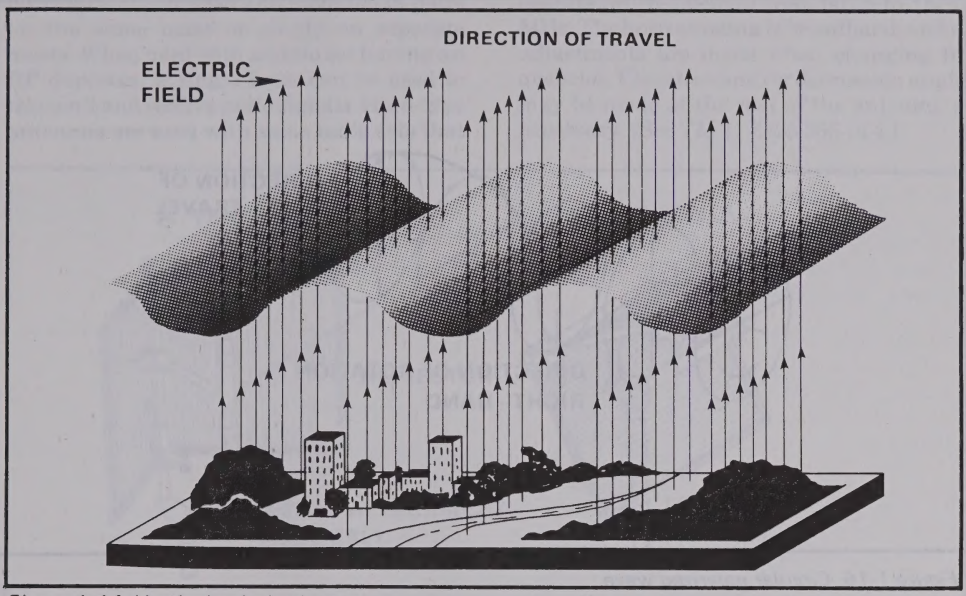

Figure 1-14. Vertical polarized wave.

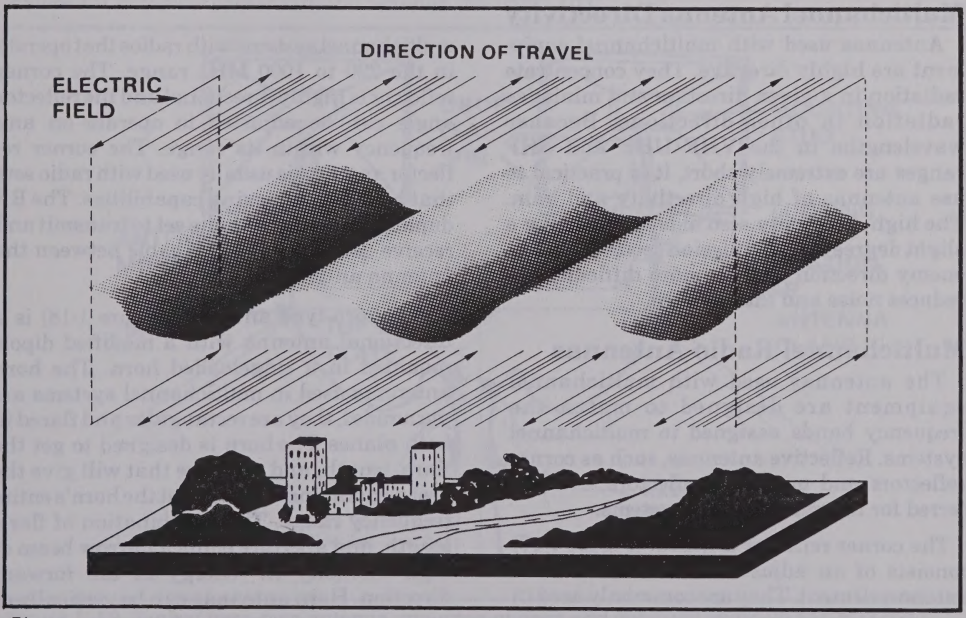

Figure 1-15. Horizontal polarized wave.

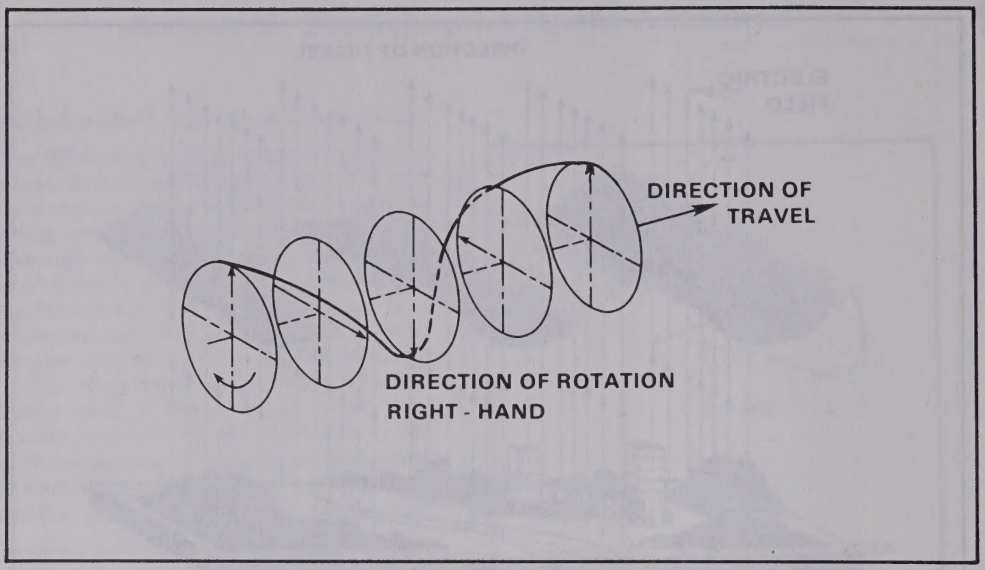

Figure 1-16. Circular polarized wave.

Multichannel Antenna Directivity

Antennas used with multichannel equipment are highly directive. They concentrate radiation in a given direction and minimize radiation in other directions. Because wavelengths in the VHF/UHF and SHF ranges are extremely short, it is practical to use antennas of high directivity and gain. The high directivity also aids in obtaining a slight degree of transmission security, makes enemy direction finding more difficult, and reduces noise and interference.

Multichannel Radio Antennas

The antennas used with multichannel equipment are designed to match the frequency bands assigned to multichannel systems. Reflective antennas, such as corner reflectors and parabolic reflectors, are preferred for the multichannel systems.

The corner reflector antenna (Figure 1-17) consists of an adjustable reflector and an antenna element. They are commonly used in multichannel systems with radios that operate in the 220 to 1000 MHz range. The corner reflector is highly directional and the reflector angle can be adjusted to operate on any frequency within its range. The corner reflector antenna is usually used with radio sets that have RF duplexing capabilities. The RF duplexer permits the radio set to transmit and receive using one coaxial cable between the antenna and the radio set.

The horn-type antenna (Figure 1-18) is a directional antenna with a modified dipole mounted in a ridgeloaded horn. The horn antennas used in multichannel systems are pyramidal, they are rectangular and flared in both planes. The horn is designed to get the flare, length, and aperture that will give the best performance throughout the horn's entire frequency range. This combination of flare, length, and aperture emits a narrow beam of high intensity RF energy in the forward direction. Horn antennas can be vertically or

horizontally polarized and mounted in pairs on the same mast or singly on separate masts. When used with a radio set having an RF duplexer, a single horn can be used to transmit and receive radio signals. Horn-type antennas are used with some radio sets that operate on frequencies from 601.5 to 1849.5 MHz. The horn antenna is broadband, and no adjustments are made when changing frequencies. Elevation and/or depression angles may be made at the rear of the antenna, as necessary. (See TM 11-5895-366-14-2.)

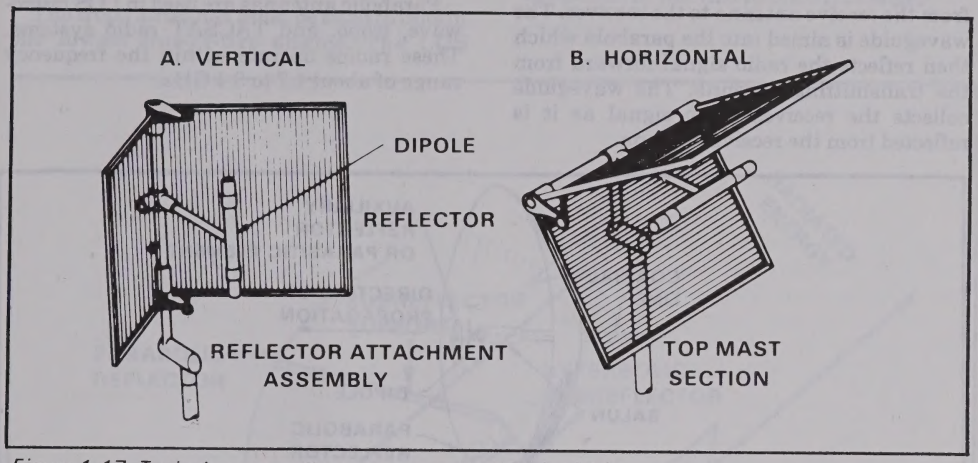

Figure 1-17. Typical corner reflector antenna (AN/GRC-103).

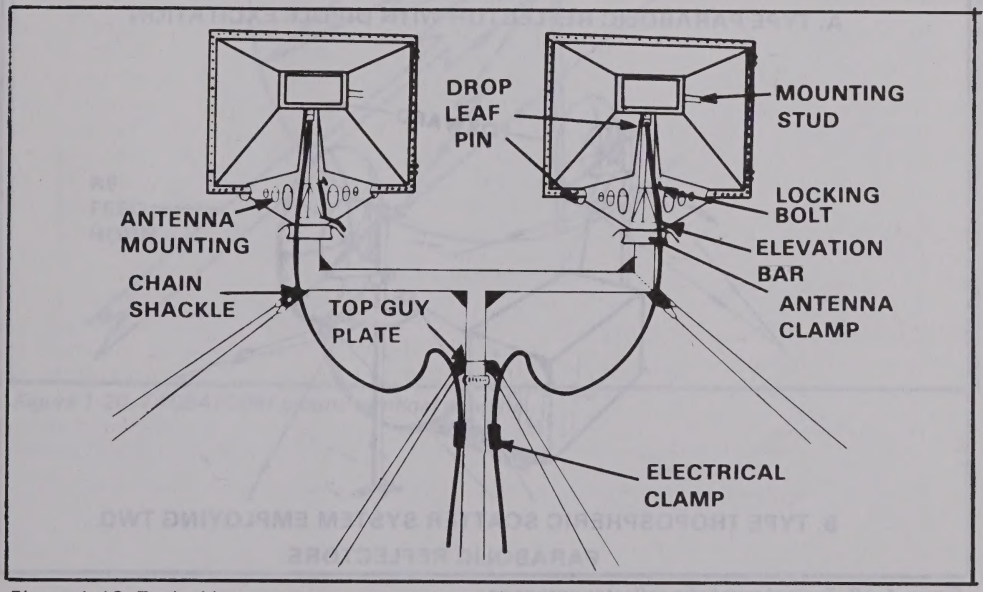

Figure 1-18. Typical horn-type antenna, mounted in pairs and polarized vertically (AT-903/G).

A parabolic reflector antenna (Figure 1-19) consists of a saucerlike reflecting surface (parabola) with waveguide and a dipole (feed devices) placed at its focal point.

□ The waveguide carries the signal from the transmitter to the transmit antenna and from the receive antenna to the receiver. The waveguide is aimed into the parabola which then reflects the radio signal forward from the transmitting antenna. The waveguide collects the received radio signal as it is reflected from the receive antenna.

□ A parasitic element or a small auxiliary reflector is placed in front of the dipole to direct more RF energy into the parabola. The dipole then functions the same as the waveguide for emitting and collecting the radio signal.

Parabolic antennas are used in LOS microwave, tropo, and TACSAT radio systems. These radios operate within the frequency range of about 1.7 to 8.4 GHz.

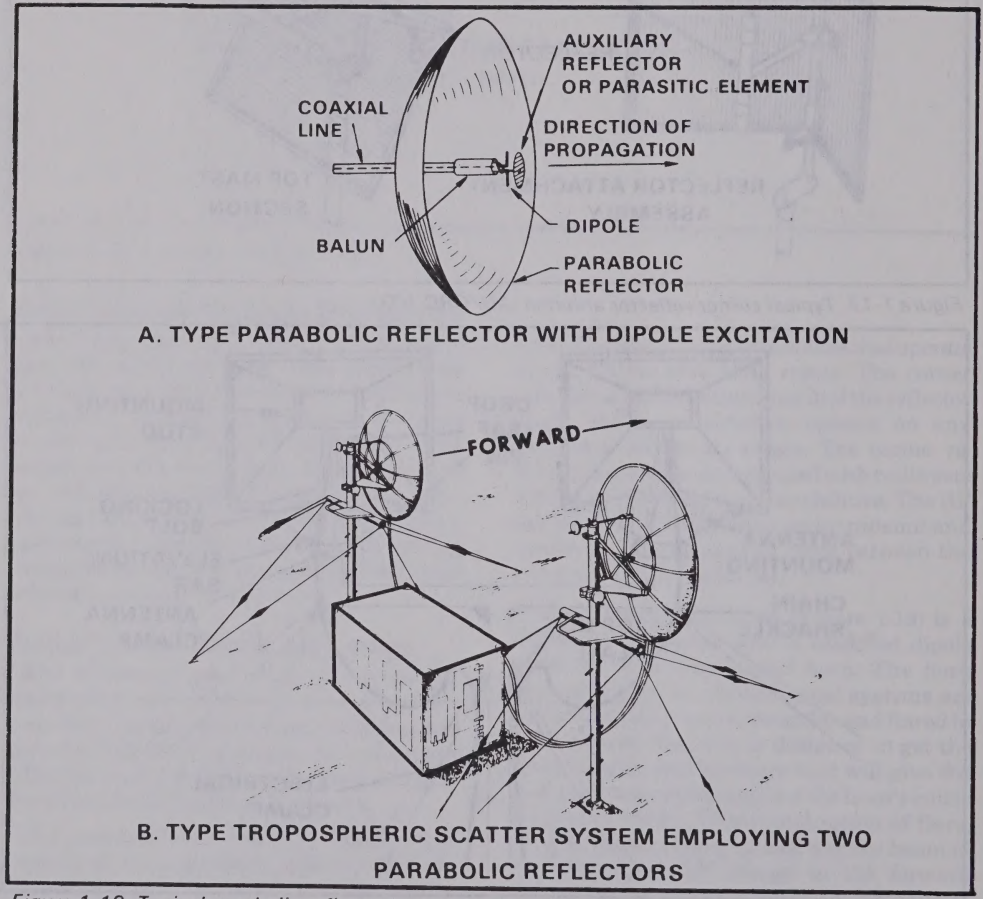

Figure 1-19. Typical parabolic reflector antennas.

The parabolic antennas' reflector surface can be solid or perforated. To reduce wind resistance, some of the larger antennas have perforated surfaces or grid wires in which the spacings are a precalculated fraction of a wavelength.

The tropo antennas must be sited to obtain the lowest line-of-fire angles. The LOS microwave antennas must be sited to obtain the best possible LOS path between stations.

The TACSATCOM antennas are of the parabolic type with a reflector, feed horn, and subreflector (Figure 1-20). They are designed to operate in the 7.25 to 8.4 GHz range.

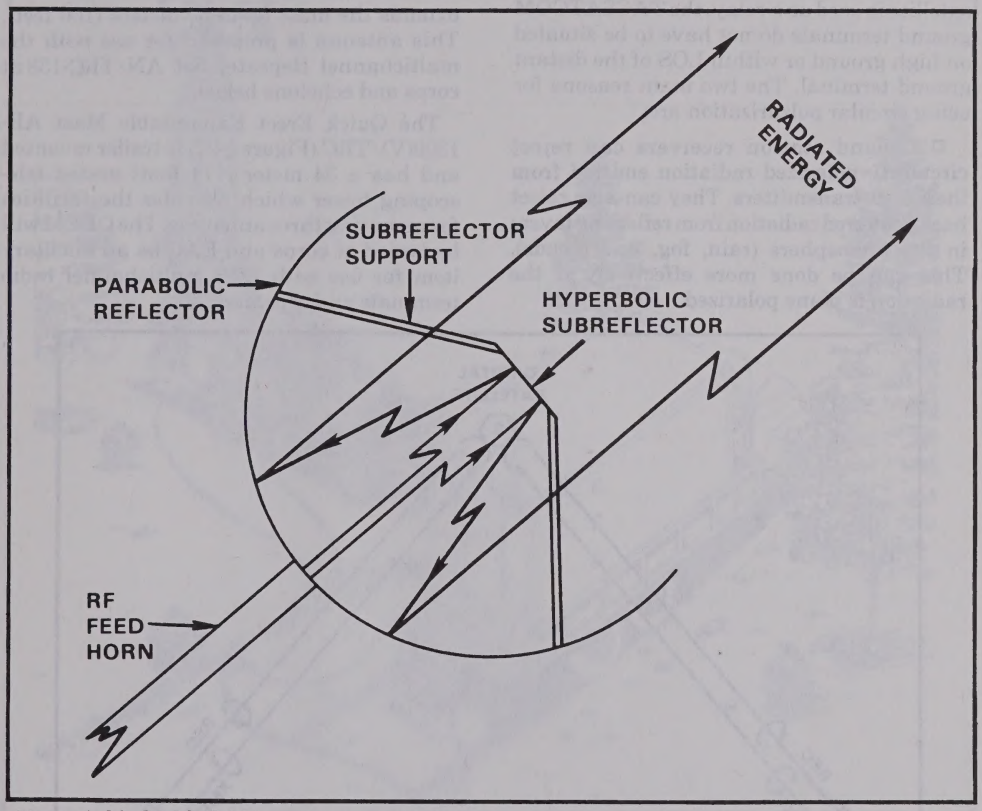

Figure 1-20. TACSATCOM ground terminal antenna.

The TACSATCOM systems use circular polarized antennas instead of plane polarized antennas. The ground terminals transmit right-hand polarization and receive left-hand polarization (Figure 1-21). Since an orbital satellite is used as a relay, the TACSATCOM ground terminals do not have to be situated on high ground or within LOS of the distant ground terminal. The two main reasons for using circular polzarization are:

□ **Ground station receivers can reject circularly polarized radiation emitted from their own transmitters. They can also reject back-scattered radiation from reflecting layers in the atmosphere (rain, fog, and clouds). This can be done more effectively if the radiation is plane polarized.**

□ **Circular polarization makes polarization alignment control unnecessary.**

The antenna AB-621A/G, an improved version of the AB-621/G, has connections for the MX-2024 extension kit. The extension kit extends the mast up to 30 meters (100 feet). This antenna is proposed for use with the multichannel Repeater Set AN/TRC-138 at corps and echelons below.

The Quick Erect Expandable Mast AB-1309(V)/TRC (Figure 1-22) is trailer mounted and has a 34 meter (114 foot) nested telescoping tower which provides the facilities for mounting three antennas. The QEEM will be issued at corps and EAC as an ancillary item for use with LOS multichannel radio terminals and repeaters.

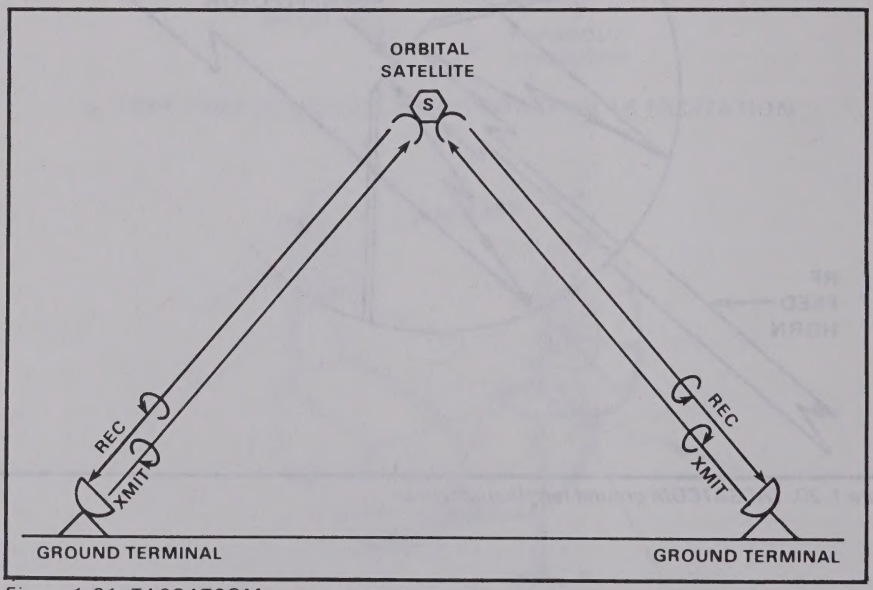

Figure 1-21. TACSATCOM system.

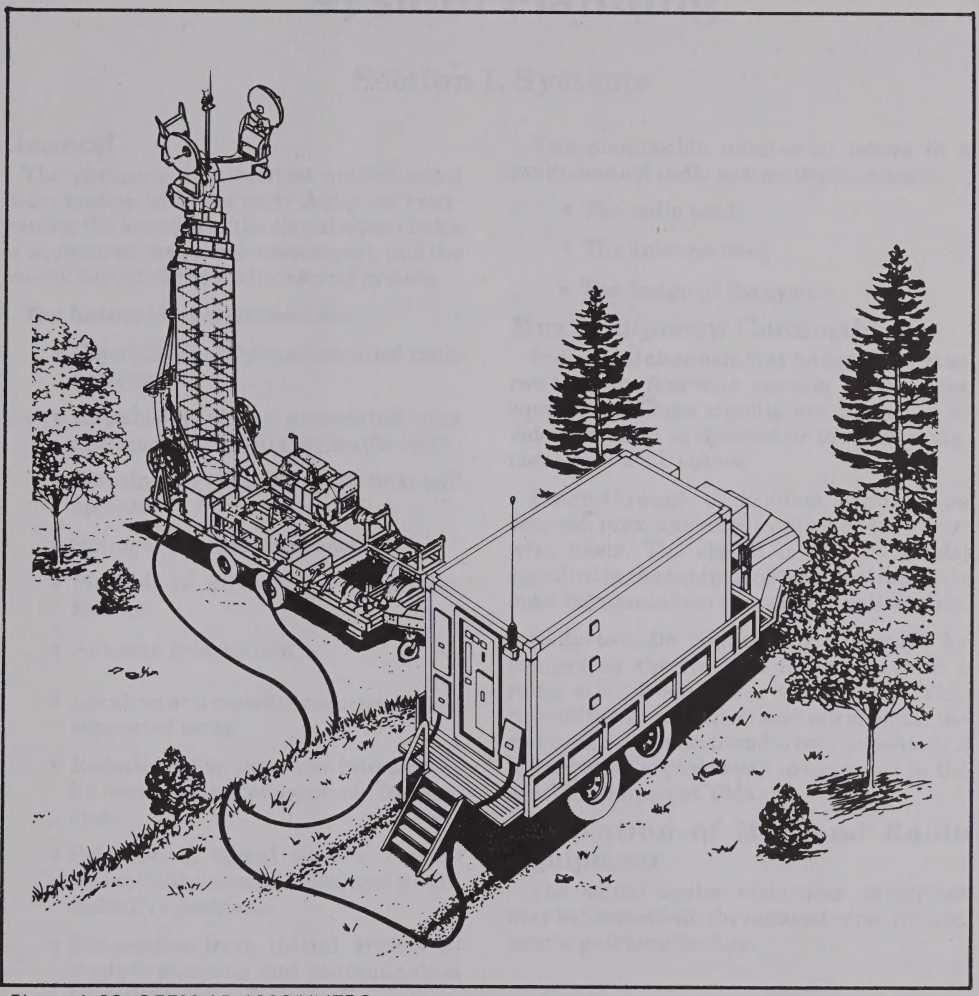

Figure 1-22. QEEM AB-1309(V)/TRC.

Chapter 2

System Planning

Section I. Systems

General

The planning of a tactical multichannel radio system involves such things as determining the location of the signal sites, choice of equipment, frequency assessment, and the overall layout of the multichannel system.

The factors to be considered are:

- Capabilities of the multichannel radio equipment.
- Capability of the associated mux equipment to handle the traffic load.
- Terrain over which the radio links will operate.
- Siting of the radio antennas.
- Methods of minimizing radio interference.
- Antenna polarization.
- Location and mobility requirements of supported units.
- Reduction of mutual radio interference by best selection of available frequencies.
- Selection of signal sites to provide accessibility, escape route, and good defensive positions.
- Protection from initial effects of nuclear weapons and contamination (chemical and radiological).

Systems Considerations

A multichannel radio system may be used to provide direct radio-linked communications trunks or to provide a link in a cable system.

The permissible number of relays in a multichannel radio system depends upon:

- The radio used.
- The antenna used.
- The design of the system.

Mux Equipment Connections

Individual channels may be brought out as two-wire or four-wire circuits at the mux equipment. These circuits are connected to voice terminal equipment or to other equipment with a VF output.

Patch-through or tandem connections between mux equipment are made on a four-wire basis. The signal levels (db levels) specified in the equipment technical manuals must be maintained to ensure circuit quality.

Radio-to-radio connections are made by connecting the received radio signal at a relay site directly to a transmitter. This reconditions, amplifies, and retransmits the radio signal. Radio-to-radio connections, and the required signal levels are covered in the specific equipment TMs.

Separation of Mux and Radio Equipment

The signal center node mux equipment may be located with the radio set or centralized near a patching facility.

The mux and radio are normally housed in the same shelter/vehicle at division and lower levels. This arrangement reduces setup and teardown time, personnel requirements, vehicles, and power generator sets. This arrangement also reduces the signature of the signal node.

The split terminal arrangement is normally used at EAD level. The mux will normally be centralized near a patching facility. The radio terminals will be located away from the congestion of the signal center proper. PCM cable connects the radio terminal to the mux equipment. The mux equipment is then connected to the patching facility by 26-pair cable. This limits the distance from mux to patch panel to 457 meters (1,500 feet) maximum.

Section II. Techniques of System Placement

Relay Sites

There are many factors to be considered when planning the multichannel radio terminal and relay sites.

Physical security is one of the major factors to consider. This is discussed in Chapter 8.

Multichannel radio systems with radio relay stations usually follow a zigzag course since terrain seldom permits a straight line of relay stations. If conditions permitted the relays to be positioned in a straight line, it would decrease the amount of equipment, personnel, and logistic support required in the system. However, straight-line siting may cause frequency assignment problems because of signal overshoot. Signal overshoot occurs when radiated energy from a terminal or relay continues beyond its intended destination (the next station in the system) and is received at another station in the system with the same frequency assignment. This station could be several links away.

Selection of sites may be done by any one method or by a combination of several methods. Contour maps, military topographic maps, aerial photographs, and surveys may be used satisfactorily. Normally, tentative site locations are selected from military topographic maps (alternate tentative site locations should also be identified), and a ground or aerial reconnaissance is made to determine the exact site location. During this reconnaissance, access and escape routes, road conditions, suitability of the site for defensive positions, absence of contamination, and suitability of the ground to support vehicles and erected antennas should be checked.

A relatively flat hilltop with good drainage is usually the most desirable site location. However, if the site location is to be relatively close to the FLOT, then other factors must be considered. The antenna should be positioned so that radiated energy will not cross the FLOT. The best way to do this is to position the antenna on the side of a hill away from the FLOT (Figure 2-1), or to profile the radio systems, as nearly as possible, parallel to the FLOT (Figure 2-2). This will make it difficult for the enemy to locate your position through electronic direction-finding techniques.

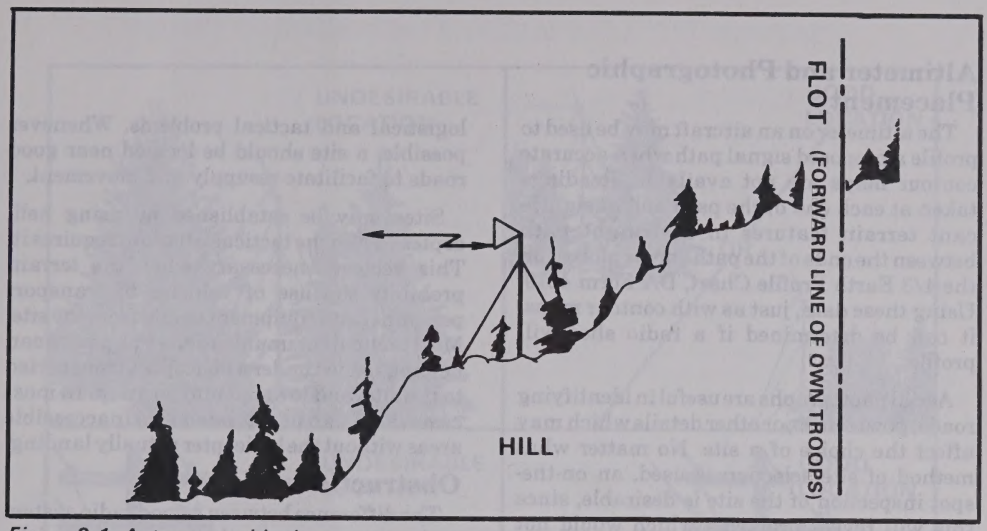

Figure 2-1. Antenna positioning.

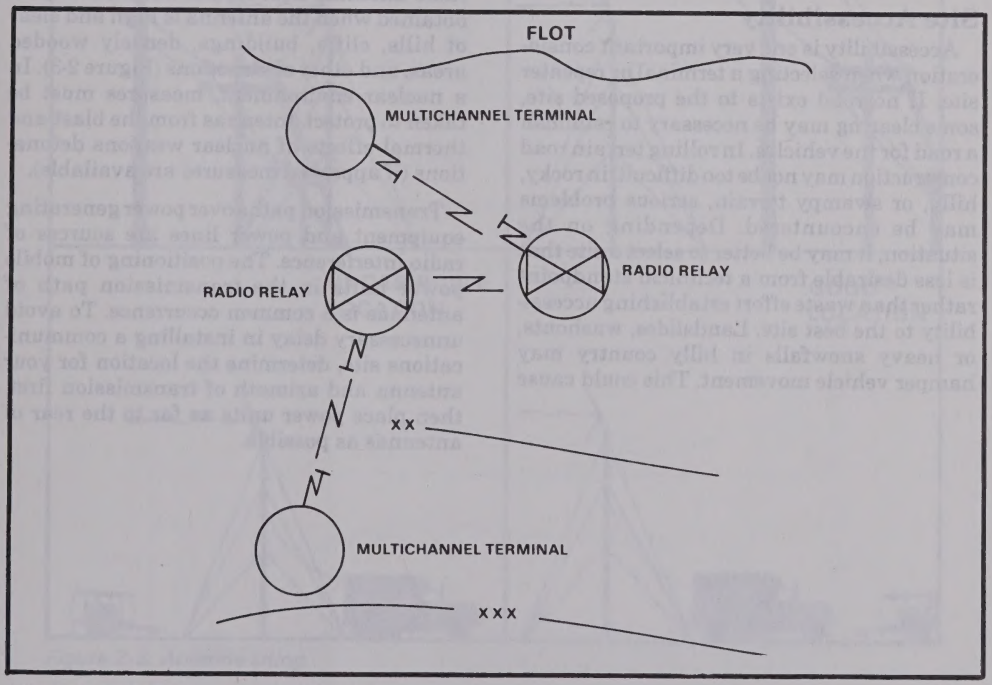

Figure 2-2. Multichannel terminal/relay siting.

Altimeter and Photographic Placement

The altimeter on an aircraft may be used to profile a proposed signal path when accurate contour maps are not available. Readings taken at each end of the path and at significant terrain features in a straight path between the ends of the path can be plotted on the 4/3 Earth Profile Chart, DA Form 4219. Using these data, just as with contour maps, it can be determined if a radio shot will profile.

Aerial photographs are useful in identifying roads, power lines, or other details which may affect the choice of a site. No matter what method of site selection is used, an on-the-spot inspection of the site is desirable, since this will reveal problems which would not otherwise be apparent.

Site Accessibility

Accessibility is one very important consideration when selecting a terminal or repeater site. If no road exists to the proposed site, some clearing may be necessary to establish a road for the vehicles. In rolling terrain road construction may not be too difficult: in rocky, hilly, or swampy terrain, serious problems may be encountered. Depending on the situation, it may be better to select a site that is less desirable from a technical standpoint rather than waste effort establishing accessibility to the best site. Landslides, washouts, or heavy snowfalls in hilly country may hamper vehicle movement. This could cause logistical and tactical problems. Whenever possible, a site should be located near good roads to facilitate resupply and movement.

Sites may be established by using helicopters when the tactical situation requires it. This becomes necessary when the terrain prohibits the use of vehicles to transport personnel and equipment to and from the site. Most tactical communications equipment can be sling-loaded under a helicopter, transported to the site, and lowered into position. In most cases, sites can be established in inaccessible areas without the helicopter actually landing.

Obstructions

The difference between a good radio system and a poor one can be the proper siting of the radio antenna. Best results will normally be obtained when the antenna is high and clear of hills, cliffs, buildings, densely wooded areas, and other obstructions (Figure 2-3). In a nuclear environment, measures must be taken to protect antennas from the blast and thermal effects of nuclear weapons detonations (if approved measures are available).

Transmission paths over power generating equipment and power lines are sources of radio interference. The positioning of mobile power units in the transmission path of antennas is a common occurrence. To avoid unnecessary delay in installing a communications site, determine the location for your antenna and azimuth of transmission first, then place power units as far to the rear of antennas as possible.

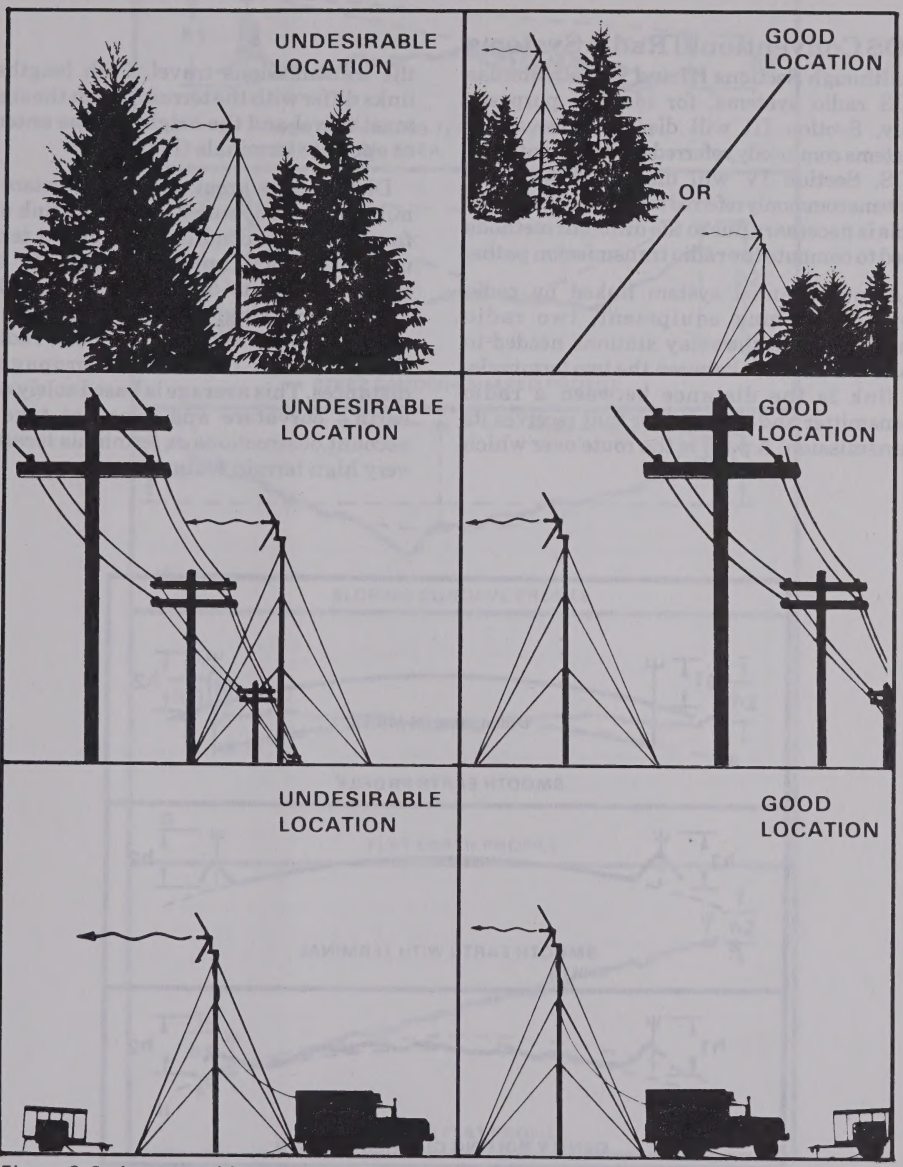

Figure 2-3. Antenna siting.

Section III. LOS Radio Transmission Paths

LOS Conventional Radio Systems

Although Sections III and IV both discuss LOS radio systems, for identity purposes only, Section III will discuss those radio systems commonly referred to as conventional LOS. Section IV will discuss those radio systems commonly referred to as LOS microwave. This is necessary due to the different methods used to compute the radio transmission paths.

A multichannel system linked by radio consists of mux equipment, two radio terminals, and the relay stations needed to span the distance between the two terminals. A link is the distance between a radio transmitter and the receiver that receives its transmission. A path is the route over which the transmissions travel. Path lengths for links differ with the terrain which the signals must travel and the heights of the antennas at opposite terminals (Figure 2-4).

Distances as great as 160 kilometers (100 miles) may be spanned in a single link under favorable LOS conditions. Over flat terrain, using standard antenna masts, 40 to 80 kilometers (25 to 50 miles) can usually be spanned in a single link. In computing LOS radio paths, 48 kilometer (30 mile) radius is the yardstick for average propagation distances. This average is based solely on the earth's curvature and does not take into account obstructions or terminals located on very high terrain features.

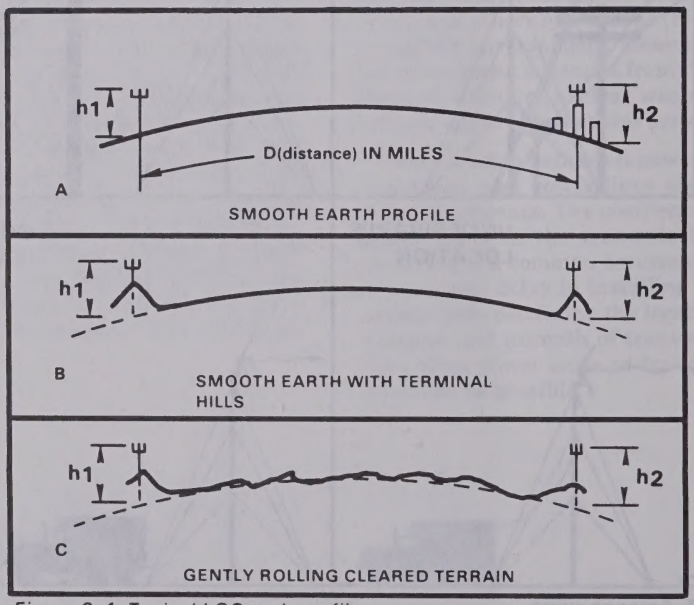

Figure 2-4. Typical LOS path profiles.

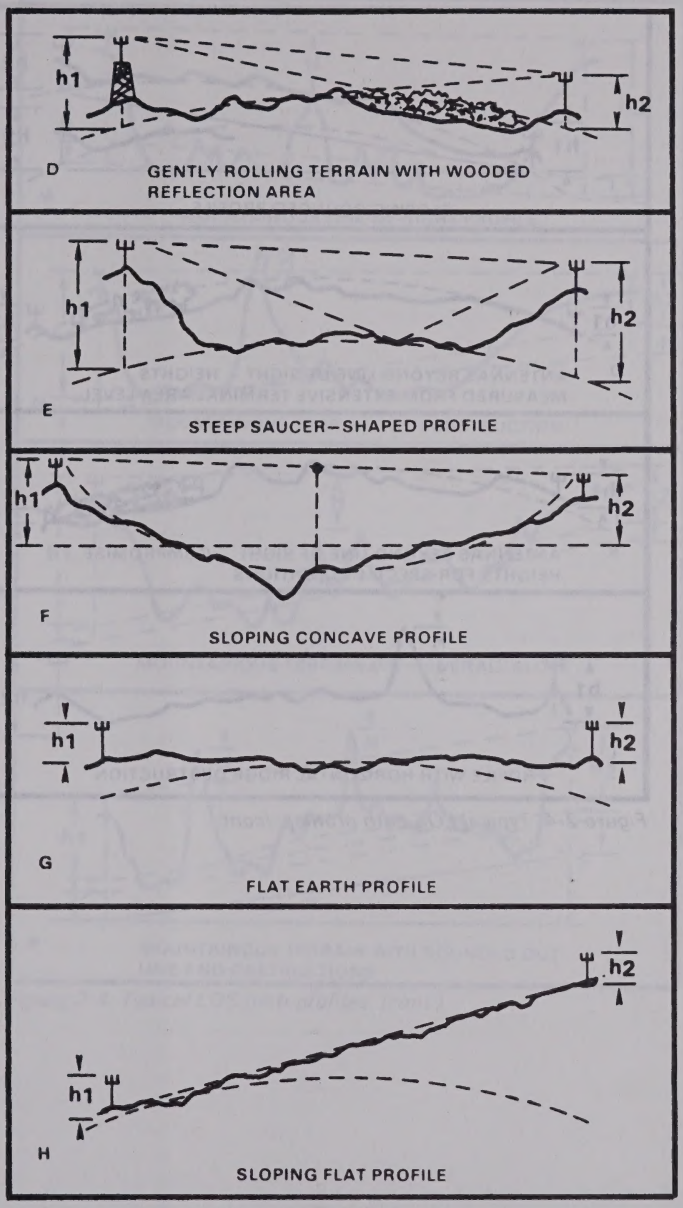

Figure 2-4. Typical LOS path profiles. (cont.)

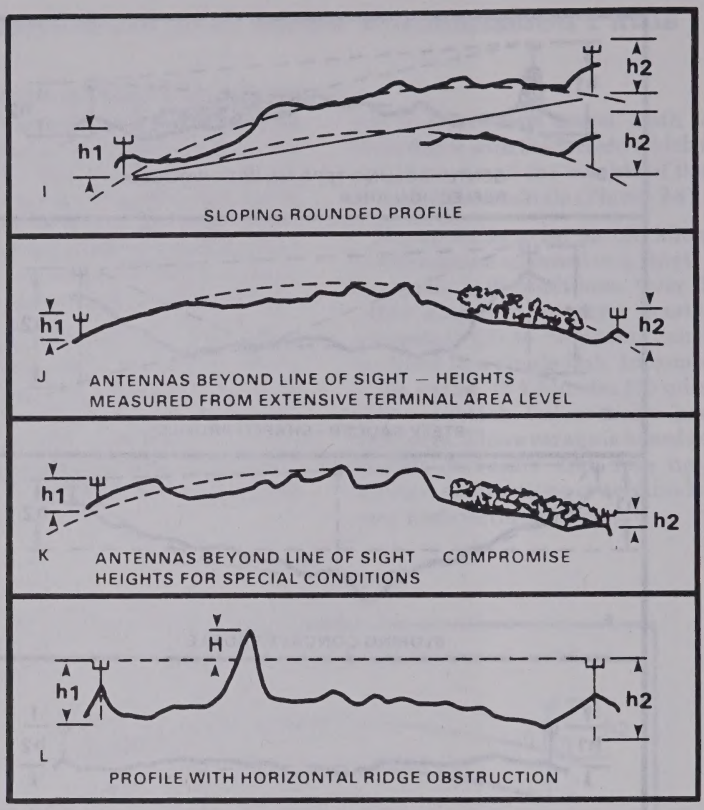

Figure 2-4. Typical LOS path profiles. (cont.)

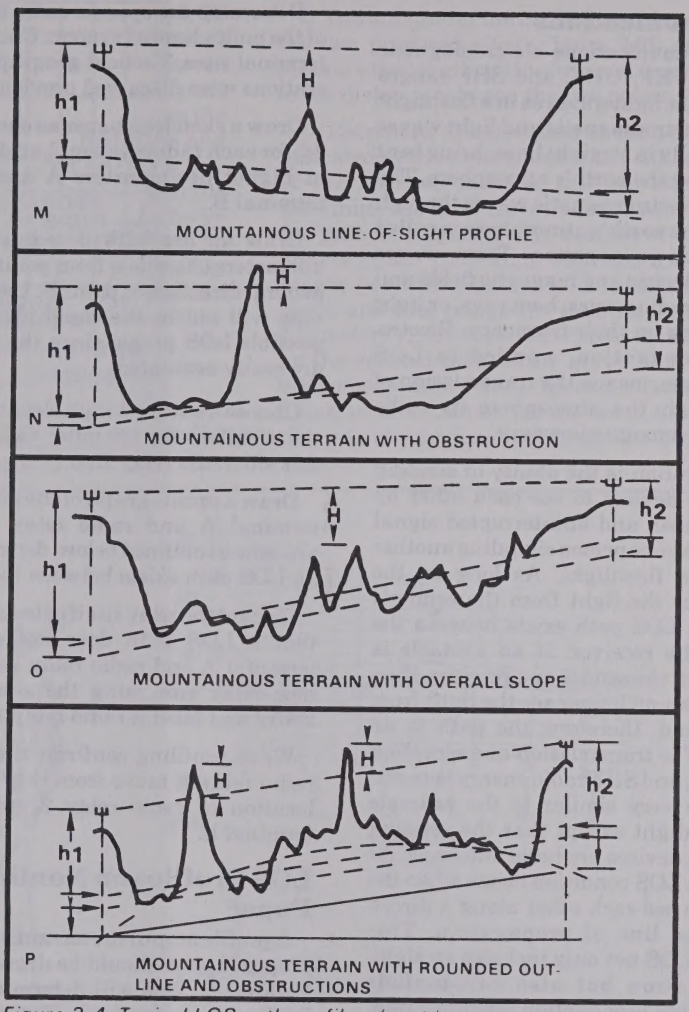

Figure 2-4. Typical LOS path profiles. (cont.)

LOS Communications

In LOS communications electromagnetic waves in the VHF, UHF, and SHF ranges behave much like light waves as in a flashlight beam. Both electromagnetic and light waves travel essentially in straight lines, being bent only slightly by the earth's atmosphere. The movement of electromagnetic waves through free space or the earth's atmosphere is called electromagnetic propagation. These waves vary in their electric and magnetic fields and are known as radio waves, heat rays, or light rays, depending on their frequency. Electromagnetic propagation, applied to LOS communications, means the transmission of signals through the atmosphere by radio produced electromagnetic waves.

LOS propagation is the ability of sending and receiving devices to see each other by following a direct and uninterrupted signal path. This is like one person signaling another person with a flashlight. As long as the person can see the light from the sender's flashlight, an LOS path exists between the sender and the receiver. If an obstacle is placed between the sender and receiver, then the receiver can no longer see the light from the sender; and, therefore, the path is no longer LOS. The transmission and reception of VHF, UHF, and SHF radio energy between two points is very similar to the example using a flashlight except that the sending and receiving devices are radio antennas. As with light, an LOS condition exists when the antennas can see each other along a direct, uninterrupted line of propagation. This definition of LOS not only includes straight-line propagation but also can include nonstraight-line propagation resulting from the refraction or bending properties of the earth's atmosphere.

LOS Procedures

The procedures for planning a signal path for LOS radio and radio relay links in a multichannel system are outlined below. These procedures apply to planning each path in a system of interconnecting or parallel paths.

Determine the specific radio terminal sites of the multichannel system. Choose the exact terminal sites. Tactical geographical considerations were discussed previously.

Draw a sketch on paper as shown in Figure 2-5 for each radio system. Label the terminal at higher headquarters A and the distant terminal B.

Draw an arc with a radius of about 48 kilometers (30 miles) from point A and in the general direction of point B. Use of a contour map will aid in the rapid identification of possible LOS paths, since the contour lines are easily evaluated.

Choose a site with high elevation on or near the 48-kilometer (30-mile) radius and label this site radio relay 1.

Draw a profile graph of the ground between terminal A and radio relay 1. Using the procedures outlined below, determine whether an LOS path exists between them.

Discard the relay site if calculations indicate that a LOS path does not exist between terminal A and radio relay 1. Then select a new relay site using the same procedures above and label it radio relay 1.

When profiling confirms the suitability of radio relay 1, move from it to determine the location of radio relay 2, until you reach terminal B.

LOS Profiles on Nonlinear Graph Paper

A profile map of the terrain between the two proposed sites should be drawn as shown in Figure 2-6. This will determine whether an LOS path exists between two signal sites. Nonlinear graph paper used for plotting profiles from contour maps is shown in Figure 2-7. Either of the graphs shown in Figure 2-7 may be used, depending on the elevations and distances between the proposed sites. The upper graph is used for elevations to 1,520 meters (5,000 feet) and distances to 200 kilometers (125 miles). The lower graph is for elevations to 152 meters (500 feet) and distances to 80 kilometers (50 miles).

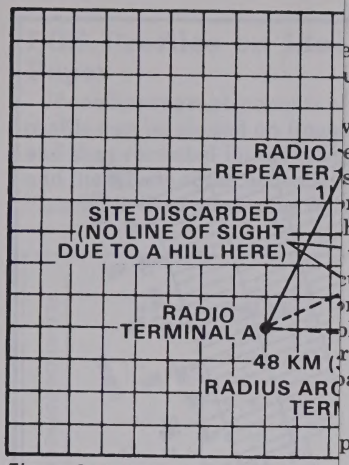

Figure 2-5. Selection of intermedi

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□ Draw a line on the contour map between the two proposed sites (Figure 2-6E or H). Measure the length of this line and convert it to the distance between the two points.

□ Determine the elevation at each site as indicated by the contour lines. Add the height of the antenna mast to this elevation to determine the total elevation. For example--for path D (Figure 2-6H), station N is 411 meters (1,350 feet) high. Add the antenna height (we will estimate it is 15 meters (50 feet)), and this brings the total elevation to 426 meters (1,400 feet). This point is marked on the vertical scale of the graph above the 0-kilometer/mile point (Figure 2-6J.) Station 0 has an elevation of 426 meters (1,400 feet) plus an antenna height of 15 meters (50 feet),

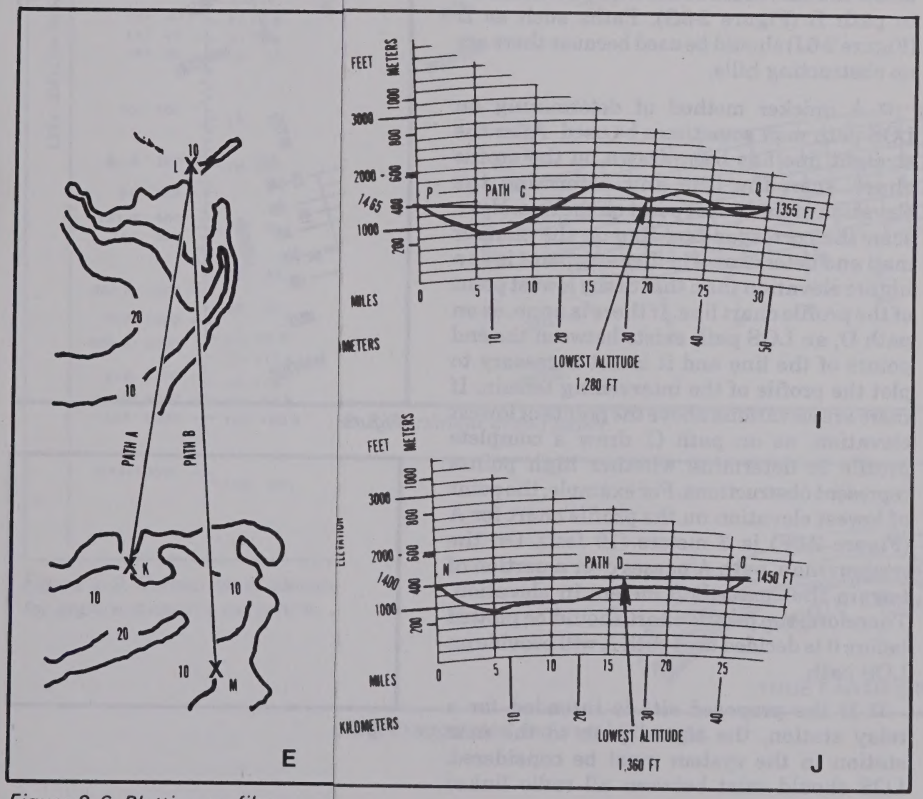

Figure 2-6. Plotting profiles.

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LOS propagation is the ability of sending and receiving devices to see each other by following a direct and uninterrupted signal path. This is like one person signaling another person with a flashlight. As long as the person can see the light from the sender's flashlight, an LOS path exists between the sender and the receiver. If an obstacle is placed between the sender and receiver, then the receiver can no longer see the light from the sender; and, therefore, the path is no longer LOS. The transmission and reception of VHF, UHF, and SHF radio energy between two points is very similar to the example using a flashlight except that the sending and receiving devices are radio antennas. As with light, an LOS condition exists when the antennas can see each other along a direct, uninterrupted line of propagation. This definition of LOS not only includes straight-line propagation but also can include nonstraight-line propagation resulting from the refraction or bending properties of the earth's atmosphere.

LOS Procedures

The procedures for planning a signal path for LOS radio and radio relay links in a multichannel system are outlined below. These procedures apply to planning each path in a system of interconnecting or parallel paths.

Determine the specific radio terminal sites of the multichannel system. Choose the exact terminal sites. Tactical geographical considerations were discussed previously.

Draw a sketch on paper as shown in Figure 2-5 for each radio system. Label the terminal at higher headquarters A and the distant terminal B.

Draw an arc with a radius of about 48 kilometers (30 miles) from point A and in the general direction of point B. Use of a contour map will aid in the rapid identification of possible LOS paths, since the contour lines are easily evaluated.

Choose a site with high elevation on or near the 48-kilometer (30-mile) radius and label this site radio relay 1.

Draw a profile graph of the ground between terminal A and radio relay 1. Using the procedures outlined below, determine whether an LOS path exists between them.

Discard the relay site if calculations indicate that a LOS path does not exist between terminal A and radio relay 1. Then select a new relay site using the same procedures above and label it radio relay 1.

When profiling confirms the suitability of radio relay 1, move from it to determine the location of radio relay 2, until you reach terminal B.

LOS Profiles on Nonlinear Graph Paper

A profile map of the terrain between the two proposed sites should be drawn as shown in Figure 2-6. This will determine whether an LOS path exists between two signal sites. Nonlinear graph paper used for plotting profiles from contour maps is shown in Figure 2-7. Either of the graphs shown in Figure 2-7 may be used, depending on the elevations and distances between the proposed sites. The upper graph is used for elevations to 1,520 meters (5,000 feet) and distances to 200 kilometers (125 miles). The lower graph is for elevations to 152 meters (500 feet) and distances to 80 kilometers (50 miles).

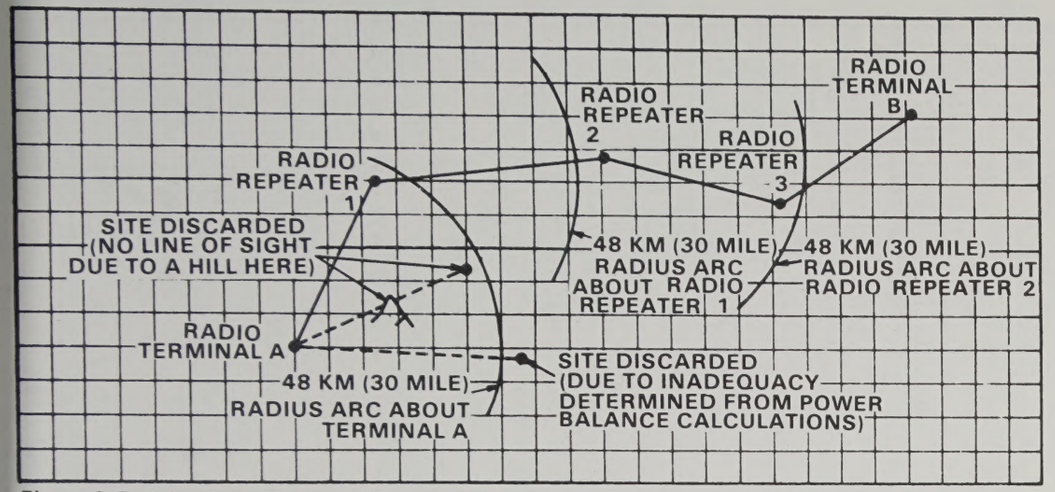

RADIO TERMINAL B
RADIO REPEATER 2
RADIO REPEATER 3
RADIO REPEATER 1
SITE DISCARDED (NO LINE OF SIGHT DUE TO A HILL HERE)
48 KM (30 MILE) RADIUS ARC ABOUT RADIO REPEATER 1
48 KM (30 MILE) RADIUS ARC ABOUT RADIO REPEATER 2
RADIO TERMINAL A
48 KM (30 MILE) RADIUS ARC ABOUT TERMINAL A
SITE DISCARDED (DUE TO INADEQUACY DETERMINED FROM POWER BALANCE CALCULATIONS)

Figure 2-5. Selection of intermediate radio sites.

Figure 2-8A shows an exaggerated LOS path on a true earth radius scale. Note that the true LOS transmission path is curved with respect to the theoretical LOS path (straight broken line). Figure 2-8B shows the true LOS path drawn as a straight line and the earth's radius expanded to 4/3 of its true size. The concept of a 4/3 radius earth profile helps in the investigation of signal paths by allowing the actual propagation path to be drawn in a straight line instead of a curve. The 4/3 radius earth compensates for the normal refraction of the earth's atmosphere. Nonlinear graph paper is designed for this purpose. When using nonlinear graph paper, use the following procedures:

□ Determine from the contour map the scales used for the distances involved.

□ Draw a line on the contour map between the two proposed sites (Figure 2-6E or H). Measure the length of this line and convert it to the distance between the two points.

□ Determine the elevation at each site as indicated by the contour lines. Add the height of the antenna mast to this elevation to determine the total elevation. For example--for path D (Figure 2-6H), station N is 411 meters (1,350 feet) high. Add the antenna height (we will estimate it is 15 meters (50 feet)), and this brings the total elevation to 426 meters (1,400 feet). This point is marked on the vertical scale of the graph above the 0-kilometer/mile point (Figure 2-6J.) Station 0 has an elevation of 426 meters (1,400 feet) plus an antenna height of 15 meters (50 feet),

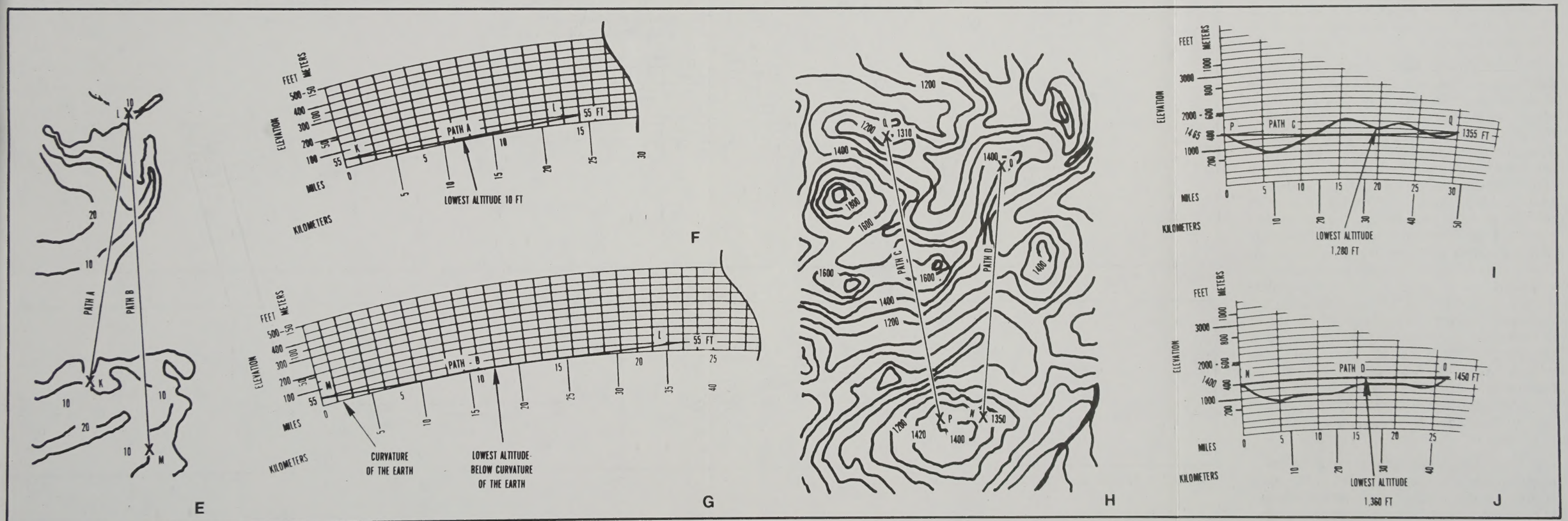
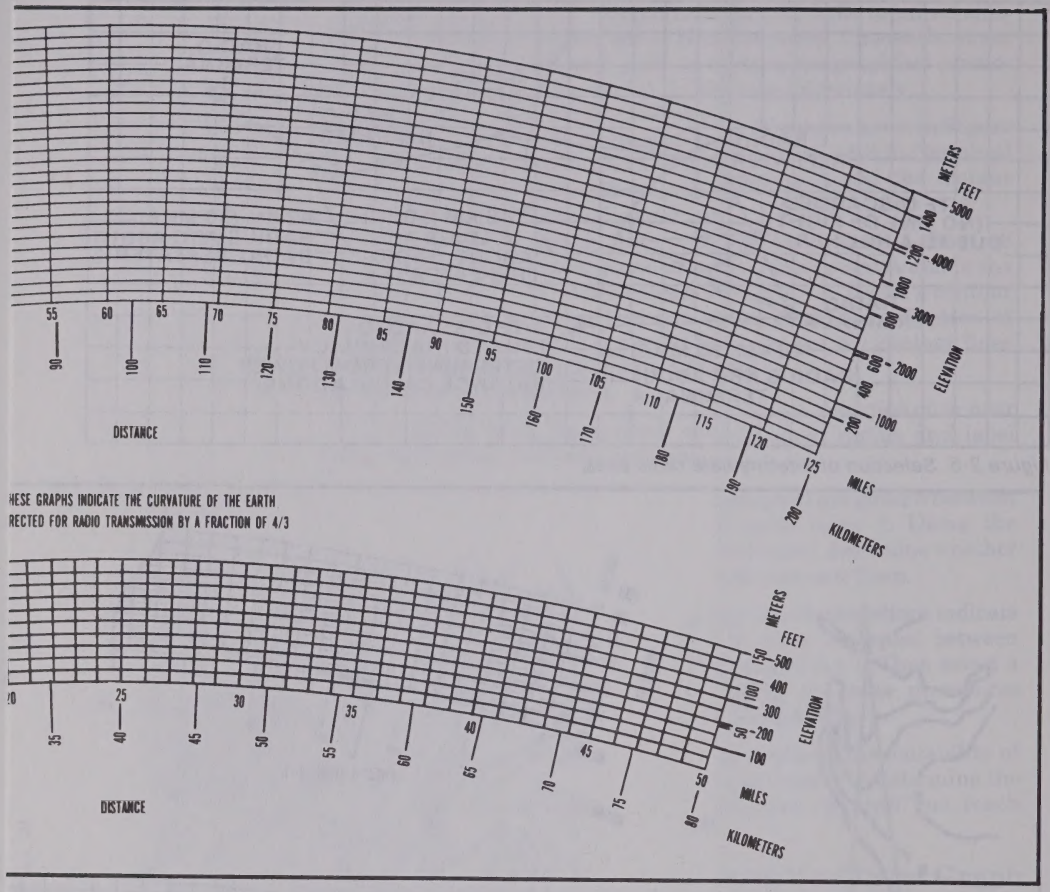
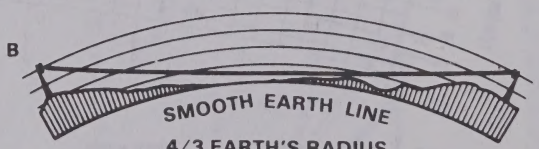


Figure 2-6. Plotting profiles.


METERS
FEET
5000
4000
3000
2000
1000
ELEVATION
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
90 100 110 120 130 140 150 160 170 180 190 200
DISTANCE
MILES
KILOMETERS
HESE GRAPHS INDICATE THE CURVATURE OF THE EARTH
RECTED FOR RADIO TRANSMISSION BY A FRACTION OF 4/3
METERS
FEET
150
500
100
400
300
50
200
100
ELEVATION
25 30 35 40 45 50 55 60 65 70 75 80
35 40 45 50 55 60 65 70 75 80
DISTANCE
MILES
KILOMETERS

F SIGHT


B
SMOOTH EARTH LINE
4/3 EARTH'S RADIUS

LOS Profiles on Linear Graph Paper

If nonlinear graph paper is not available, a profile can be plotted on linear graph paper and then corrected for curvature of the earth and the effects of refraction. Use the chart in Figure 2-9; then proceed as follows.

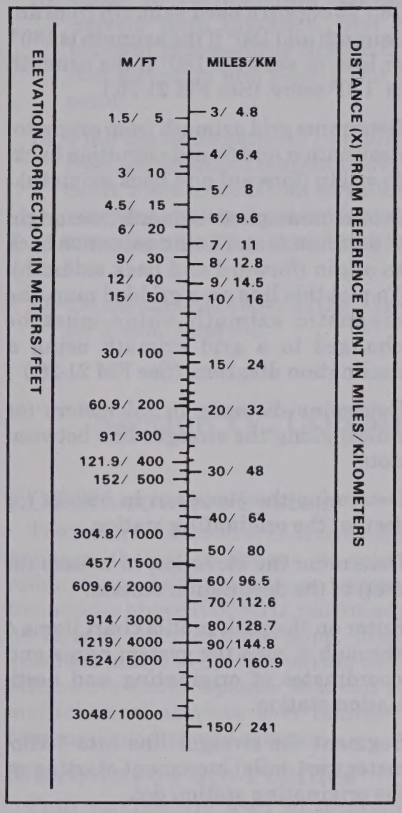


Figure 2-9. Correction of elevations to allow for apparent earth's curvature.

Determine from the contour map the scales used for distances and elevations. Draw a line on the contour map between the two proposed sites.

Pick out the high and low points along the line and plot these to scale on the linear graph paper. A sample profile is plotted as a broken line curve on this type graph paper (Figure 2-10).

Draw a line on the graph paper between terminal points A and B.

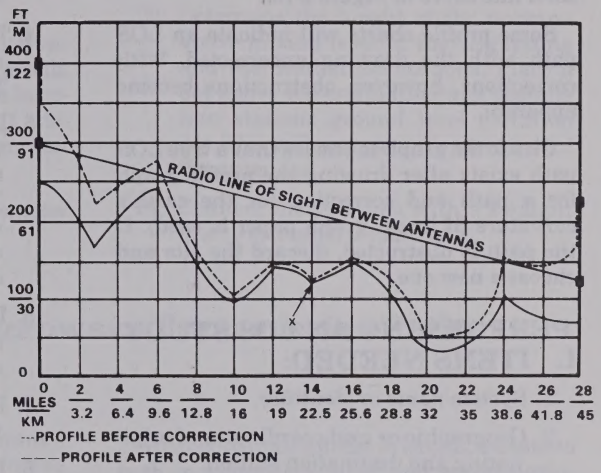


Figure 2-10. Profile plotted on linear graph paper.

giving a total elevation of 441 meters (1,450 feet). This point is marked on the vertical scale (Figure 2-6J) above the 43-kilometer (27-mile) point, because 43 kilometers is the distance between the two sites.

□ Draw a straight line between these two points on the profile chart.

□ Draw a complete profile of the terrain between the two sites. Follow the line drawn on the contour map and pick out the high and low points. Plot these points on the graph paper and join them with a line. All points that are above the straight line on the graph (Figure 2-6I) represent obstructing terrain.

□ Poor communications may result if hills intervene between the two proposed sites as in path C (Figure 2-6I) or if the site line is below the curvature of the earth as indicated in path B (Figure 2-6G). Paths such as D (Figure 2-6J) should be used because there are no obstructing hills.

□ A quicker method of determining an LOS path may sometimes be used. After the straight line has been drawn on the profile chart, scan the line and determine the elevation of the lowest point on the line. Next, scan the corresponding line on the contour map and determine whether any point is at a higher elevation than that of the lowest point of the profile chart line. If there is none, as on path D, an LOS path exists between the end points of the line and it is not necessary to plot the profile of the intervening terrain. If there are elevations above the points of lowest elevation, as on path C, draw a complete profile to determine whether high points represent obstructions. For example, the point of lowest elevation on the profile chart for A (Figure 2-6F) is 3 meters (10 feet). On the contour map, path A passes over a portion of terrain that exceeds 3 meters in elevation. Therefore, the profile chart should be plotted before it is decided that path A will provide an LOS path.

□ If the proposed site is intended for a relay station, the signal path to the next station in the system must be considered. LOS should exist between all radio linked points.

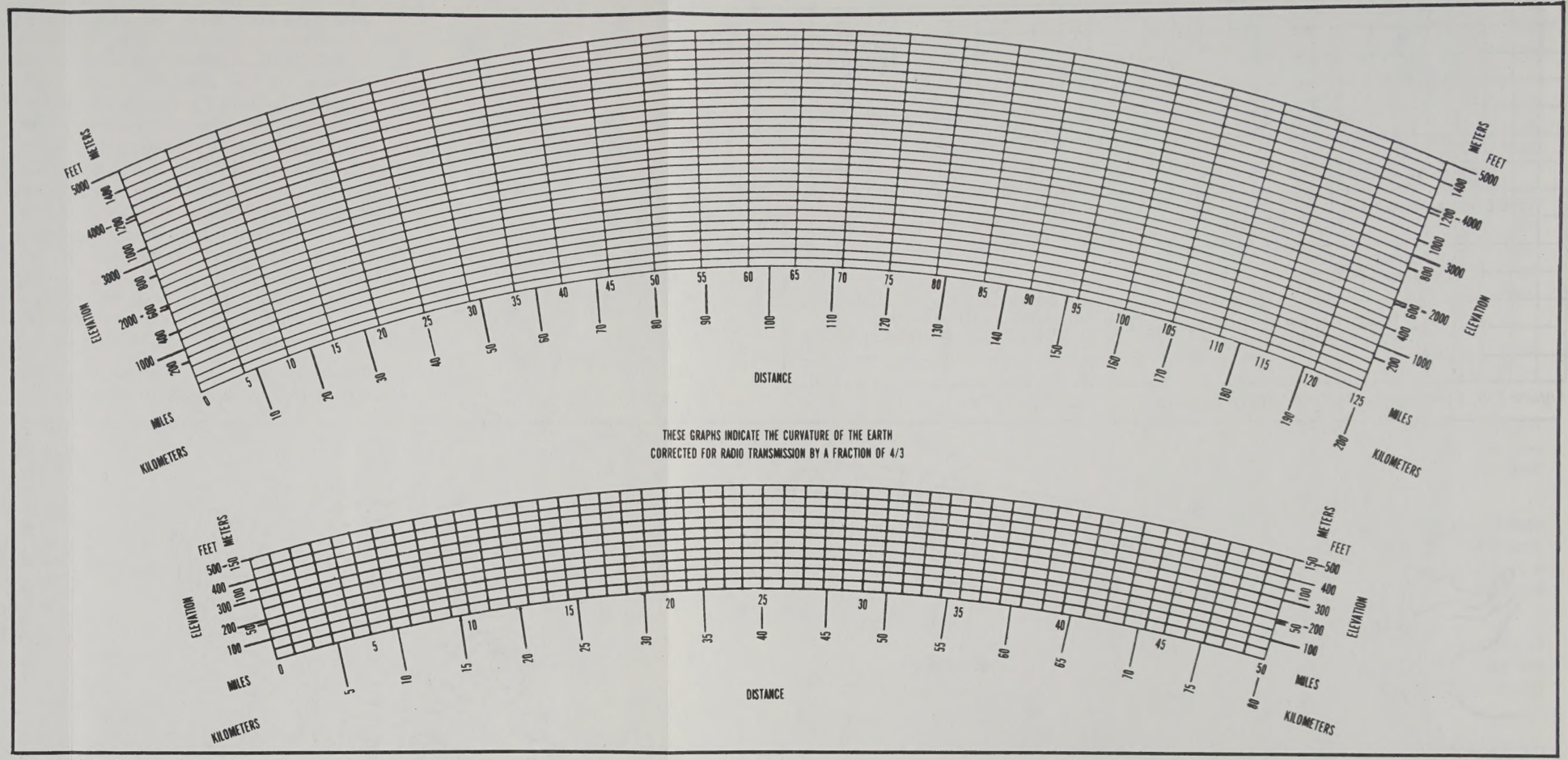


Figure 2-7. Nonlinear graph paper.

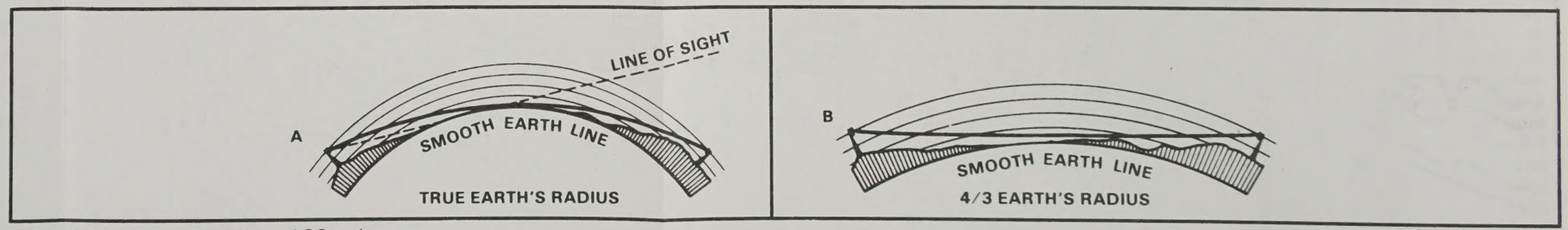


Figure 2-8. Exaggerated and true LOS paths.

LOS Profiles on Linear Graph Paper

If nonlinear graph paper is not available, a profile can be plotted on linear graph paper and then corrected for curvature of the earth and the effects of refraction. Use the chart in Figure 2-9; then proceed as follows.

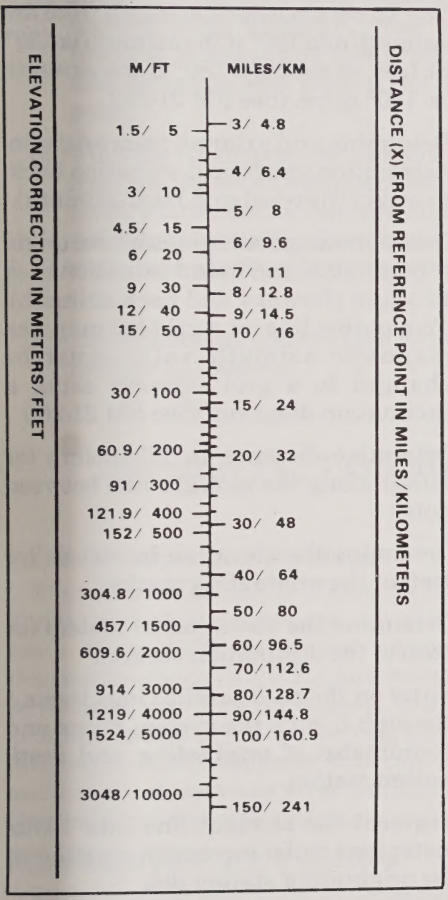


Figure 2-9. Correction of elevations to allow for apparent earth's curvature.

Determine from the contour map the scales used for distances and elevations. Draw a line on the contour map between the two proposed sites.

Pick out the high and low points along the line and plot these to scale on the linear graph paper. A sample profile is plotted as a broken line curve on this type graph paper (Figure 2-10).

Draw a line on the graph paper between terminal points A and B.

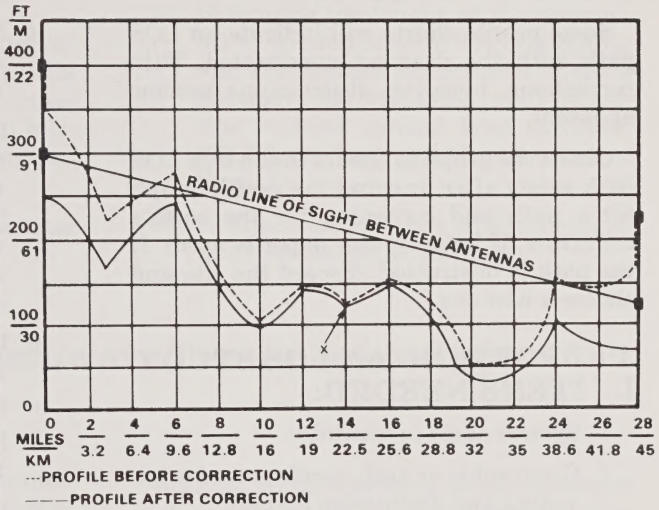


Figure 2-10. Profile plotted on linear graph paper.

Correction must be made for the curvature of the earth to obtain a true picture of the LOS. Select a high or low point that is as near as possible to the point halfway between the terminals. In Figure 2-10 the point is X. Next, by means of the figures shown in the conversion chart (Figure 2-9), convert the heights of all prominent points (shown as a solid line curve in Figure 2-10).

Some profile charts will indicate an LOS path with the drawing uncorrected. With corrections, however, obstructions become apparent.

Check the graph to ensure that a true LOS path exists after drawing the profile graph for a path and correcting for the earth's curvature (if linear graph paper is used). If the path is obstructed, discard the site and choose a new one.

PERFORMING AN LOS STUDY

I. ITEMS NEEDED:

1. System name or identifier.
2. Geographic or grid coordinates of originating and destination station.
3. Path profile chart (4/3 earth radius).
4. Topographic map.
5. GTA-5-2-10 coordinate scale, and protractor.

II. STEPS TO FOLLOW:

1. Find originating station on topographic map.
   a. Place a dot at the location.
   b. Circle the dot for ease in finding the dot later.
2. Find destination station on the same map.
   a. Place a dot at the location.
   b. Circle the dot.
3. Connect the originating station dot and the destination station dot with a straight line. GTA-5-2-10, coordinate scale should be used to determine the grid azimuth from origin to destination. (See FM 21-26.) To obtain a back azimuth from an azimuth add 180° if the azimuth is 180° or less, or subtract 180° if the azimuth is 180° more. (See FM 21-26.)
4. Determine grid azimuth from origin to destination and from destination back to origin (forward and back azimuth).
5. Determine magnetic azimuth from origin to destination and from destination back to origin (forward and back azimuth). To plot this line on a gridded map, the magnetic azimuth value must be changed to a grid azimuth using a declination diagram. (See FM 21-26.)
6. Determine distance in kilometers (or miles) along the straight line between dots.
7. Determine the elevation in meters (or feet) of the originating station.
8. Determine the elevation in meters (or feet) of the destination station.
9. Enter on the path profile chart items 4 through 8, plus the system name and coordinates of originating and destination station.
10. Segment the straight line into 1-kilometer (or 1-mile) increment starting at the originating station dot.
11. Determine the elevation in meters (or feet) at the 1-kilometer (or 1-mile) increment from the originating station.
12. Determine the elevation in meters (or feet) at the 2-kilometer (or 2-mile) increment from the originating station.
13. Determine the elevation at each succeeding interval to the destination.

14. Read up left margin of profile chart, find correct interval representing originating station elevation and place a dot there.
15. Read up vertical line representing correct path distance, find correct interval representing destination station elevation and place a dot at that point.
16. Find the 1-kilometer (or 1-mile) interval from the left-hand margin of the profile chart. Place a dot at that elevation interval representing the elevation at 1 kilometer (or mile) from the originating station.
17. Do the same as above at the 2-kilometer (or 2-mile) interval.
18. Find each succeeding 1-kilometer (or 1-mile) interval and place a dot at the elevation of each distance on the profile chart.
19. Connect the dots to establish a graphic picture of the terrain along the straight line between the origin and destination station.
20. Determine the height of the antenna above ground level of the originating and the destination stations. Place a dot above the originating and destination stations ground level elevation dot. This will represent the elevation of the antennas.
21. Connect the two dots with a straight line to establish a radio LOS.

Section IV. LOS Microwave Transmission Paths

LOS Microwave System

The factors that control LOS radio planning apply, with few exceptions, to microwave radio. Since LOS microwave systems use frequencies above 1000 MHz, antennas should be located on mountain tops, towers, or extended masts to provide terrain clearance. Microwave radio repeater sets can provide multichannel services over multiple links forming long-distance systems.

Microwave Path Profiles

Path profiles are used to determine the required heights of the transmitting and receiving antennas. Linear or nonlinear graph paper may be used to plot an LOS microwave system. Performance estimates for these systems are based on a calculated reference value. This value is equal to the free space loss plus atmospheric attenuation. Proper allowance for short-term and long-term transmission loss variations must also be made.

Microwave paths differ in length, measured both in kilometers/miles and wavelengths. Therefore, small changes in antenna height above a reflecting surface will affect the phase relationship between the radiated and the ground reflected waves. If an examination of the path profile indicates a mirror-like reflection surface, such as smooth earth, or water, add 10 to 15 db to the required path gain. This can be done by increasing the sensitivity of the receivers. The phase of the radio signal reflected from a mirror-like surface has a distinct influence on the received signal. A gain as great as 16 db may result when reflected and direct signals are in phase, but a loss of 40 db or more when they are 180° out of phase.

First Fresnel Zone Clearance

An LOS microwave radio path is computed to avoid obstacles in the vicinity of the propagation path. Microwaves passing an obstacle, such as a hilltop, a building, or a tree may have part of their strength obstructed, thus decreasing the signal level at the receiving antenna.

The first Fresnel zone (Figure 2-11) is the term used to describe that part of the propagation path in which no obstacles should be located. The first Fresnel zone is an ellipsoidal region surrounding the direct beam between antennas. Additional Fresnel zones (2d, 3d, and 4th) exist beyond the boundaries of the first Fresnel zone. Microwave systems using waveguides and parabolic antennas have about one-half the total transmitted energy in the first Fresnel zone. The first Fresnel zone also accounts for about 25 percent of the total received energy. Thus, full path clearance is desired and, if at all possible, an LOS microwave path should be laid out with first Fresnel zone clearance. Figure 2-12 is a graph for determining required obstacle clearance at any point along a path for a nominal operating frequency of 4700 MHz. Foliage and vegetation are considered to be solid earth obstacles for these determinations.

DETERMINING FIRST FRESNEL ZONE ON LOS PATH

□ After doing an LOS study on a profile chart, use the same chart and at the point where the radio line intersects the 1-kilometer (1-mile) distance line, draw another line which is at right angle to the radio line.

□ At succeeding points where the radio line intersects each 1-kilometer (1-mile) interval from the originating station, draw lines which are at right angle to the radio line.

□ Determine the frequency to be used.

□ Determine the required Fresnel zone clearance from originating to terminating station by the formula below.

-Meters/Kilometers

$$C = 17.5\sqrt{\frac{d1\ d2}{fD}}$$

-Feet/Miles

$$C = 72.1\sqrt{\frac{d1\ d2}{fD}}$$

WHERE: C = Fresnel zone clearance in meters or feet.

d1 = distance from transmit antenna to obstacle in kilometers or miles.

d2 = distance from obstacle to receive antenna in kilometers or miles.

f = Frequency in GHz.

D = Total path distance in kilometers or miles.

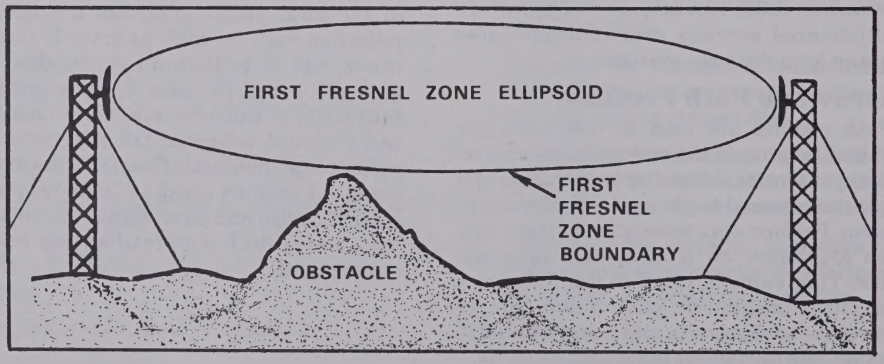


Figure 2-11. First Fresnel zone region.

□ Determine the required
clearance for each of the suc
angle lines using the above for

□ Using the elevation sca
margin of the profile chart for r
a dot on the line which has be
right angle to the radio line
increment a distance below
corresponding to the required
clearance.

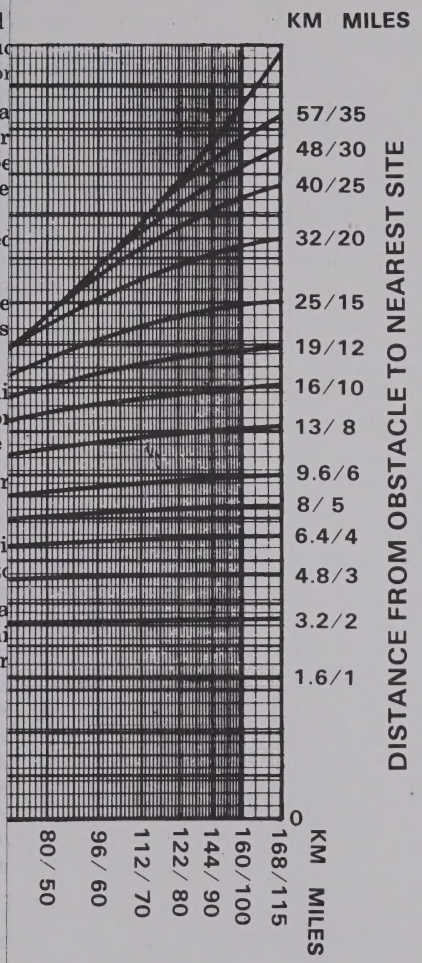
□ Place dots representing re
zone clearance for each success
lines.

□ Connect the dots to establi
Fresnel zone clearance area for
between transmit and receive

□ Find any point(s) of terr
required clearance area.

□ LOS paths are planned wi
and 100 percent first Fresnel zo

□ Look at the completed gra
the profile chart and determi
losses due to absence of requir



First Fresnel Zone Clearance

An LOS microwave radio path is computed to avoid obstacles in the vicinity of the propagation path. Microwaves passing an obstacle, such as a hilltop, a building, or a tree may have part of their strength obstructed, thus decreasing the signal level at the receiving antenna.

The first Fresnel zone (Figure 2-11) is the term used to describe that part of the propagation path in which no obstacles should be located. The first Fresnel zone is an ellipsoidal region surrounding the direct beam between antennas. Additional Fresnel zones (2d, 3d, and 4th) exist beyond the boundaries of the first Fresnel zone. Microwave systems using waveguides and parabolic antennas have about one-half the total transmitted energy in the first Fresnel zone. The first Fresnel zone also accounts for about 25 percent of the total received energy. Thus, full path clearance is desired and, if at all possible, an LOS microwave path should be laid out with first Fresnel zone clearance. Figure 2-12 is a graph for determining required obstacle clearance at any point along a path for a nominal operating frequency of 4700 MHz. Foliage and vegetation are considered to be solid earth obstacles for these determinations.

DETERMINING FIRST FRESNEL ZONE ON LOS PATH

□ After doing an LOS study on a profile chart, use the same chart and at the point where the radio line intersects the 1-kilometer (1-mile) distance line, draw another line which is at right angle to the radio line.

□ At succeeding points where the radio line intersects each 1-kilometer (1-mile) interval from the originating station, draw lines which are at right angle to the radio line.

□ Determine the frequency to be used.

□ Determine the required Fresnel zone clearance from originating to terminating station by the formula below.

-Meters/Kilometers

$$C = 17.5\sqrt{\frac{d1\ d2}{fD}}$$

-Feet/Miles

$$C = 72.1\sqrt{\frac{d1\ d2}{fD}}$$

WHERE: C = Fresnel zone clearance in meters or feet.

d1 = distance from transmit antenna to obstacle in kilometers or miles.

d2 = distance from obstacle to receive antenna in kilometers or miles.

f = Frequency in GHz.

D = Total path distance in kilometers or miles.

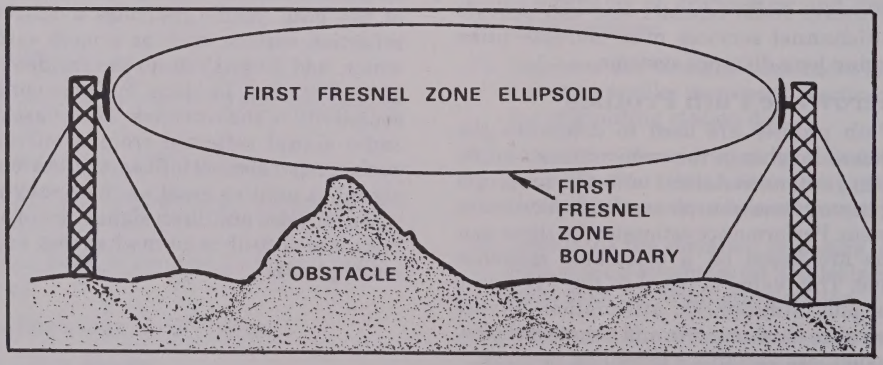


Figure 2-11. First Fresnel zone region.

□ Determine the required Fresnel zone clearance for each of the successive right-angle lines using the above formula.

□ Using the elevation scale on the left margin of the profile chart for reference, place a dot on the line which has been drawn at a right angle to the radio line at the 1-mile increment a distance below the radio line corresponding to the required Fresnel zone clearance.

□ Place dots representing required Fresnel zone clearance for each successive right-angle lines.

□ Connect the dots to establish the required Fresnel zone clearance area for the radio path between transmit and receive stations.

□ Find any point(s) of terrain inside the required clearance area.

□ LOS paths are planned within 60 percent and 100 percent first Fresnel zone clearances.

□ Look at the completed graph drawing on the profile chart and determine the sum of losses due to absence of required clearance.

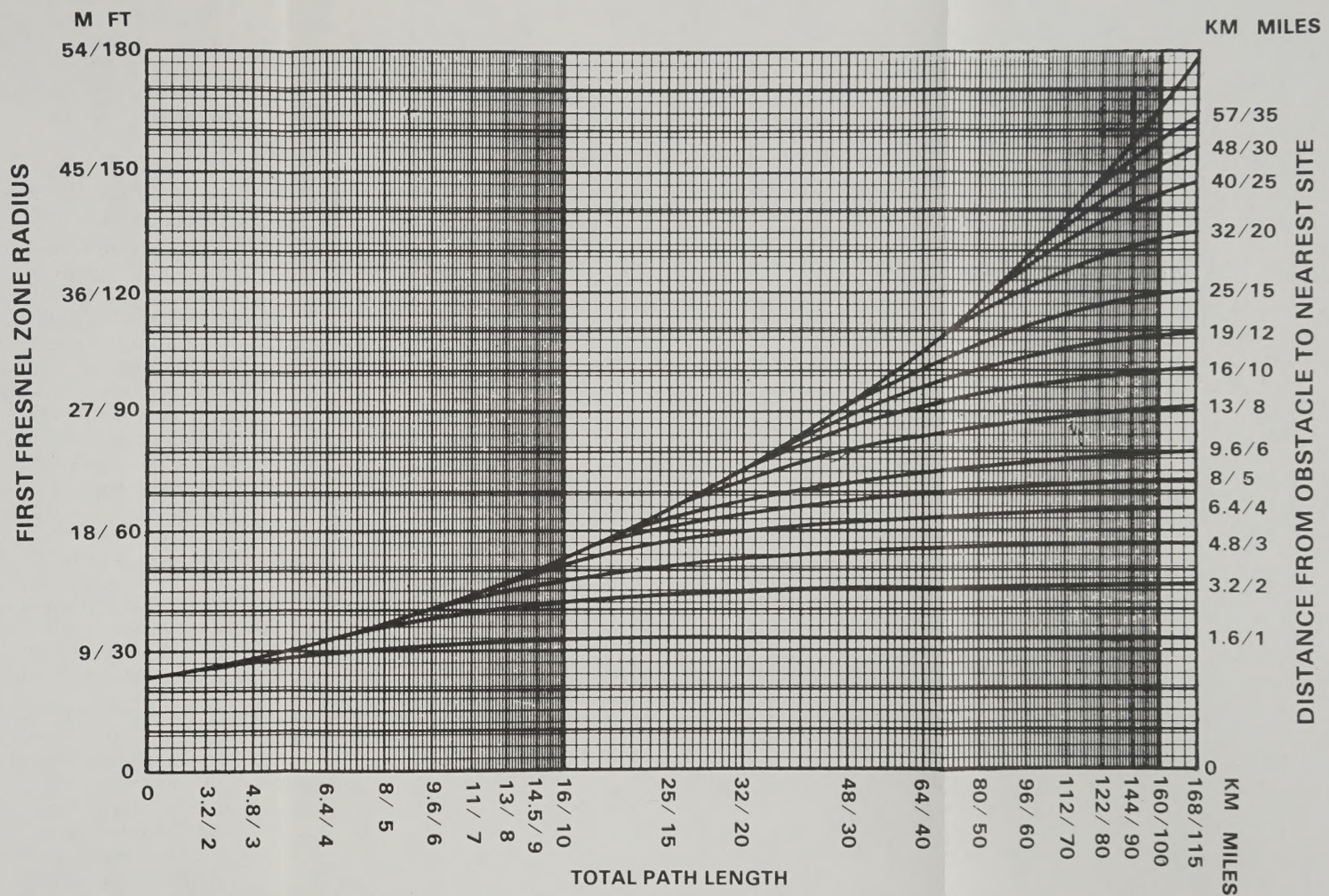


Figure 2-12. Fresnel zone radius curves.

The LOS microwave has a desired clearance of 100 percent. Good results may be obtained with only 60 percent first Fresnel zone clearance. However, it must be realized that system reliability will not be as good with this type system.

LOS Microwave Antenna Orientation

The azimuth bearing for each site with respect to the norm must be determined. Azimuth and elevation angle are given from the path study. Both ends of the system must ensure the antennas are aimed at the proper azimuth. Otherwise, the transmitted signals will miss the receiving antennas. A topographical map and a compass are used for initial positioning of the antennas. When initial radio contact is established and voice orderwire communication is in, the operators at both ends should align the antennas. First, one site moves its antenna left and right, then up and down while observing their receiver RSL for maximum indications. When maximum indication is obtained, notify the distant operator to align his antenna. Continue the procedure one at a time until maximum RSL is obtained at both ends.

The microwave antenna elevation (tilt) angles may be either zero, positive, or negative depending on the height of the terrain at the terminal sites. Figure 2-13 is a graph for determining antenna elevation angle at distances up to 160 kilometers (100 miles) and altitude differences that result in elevation angles from approximately -0.9 to +4.0°. Antenna elevation angle at a given site is determined as follows:

1. Determine the altitude difference.

   $H = H_B - H_A$

   Where H is altitude.

   Where H_A is actual altitude of the local site antenna.

   Where H_B is actual altitude of the other site.

2. Determine that the path length D is the actual path length between sites A and B.

3. Enter the graph of Figure 2-13 at the value calculated for H and D. Read the antenna elevation angle from the family of curves of angle at the intersection of points H and D.

LOS Microwave Repeater Stations

Towers are often required to raise the microwave antennas high enough so that an LOS path exists. LOS microwave links that do not have a direct LOS must use either an active or passive repeater station between the two terminals.

An active repeater is a manned station consisting of personnel to operate the equipment, two radios, associated antennas, and power generating equipment. Through the use of active repeaters, tactical LOS microwave systems of several hundred kilometers are practical. However, active repeaters have the disadvantage of requiring physical security, high cost, and continuing maintenance. Also, the number of repeater stations must be kept to a minimum in order to maintain the required received signal level.

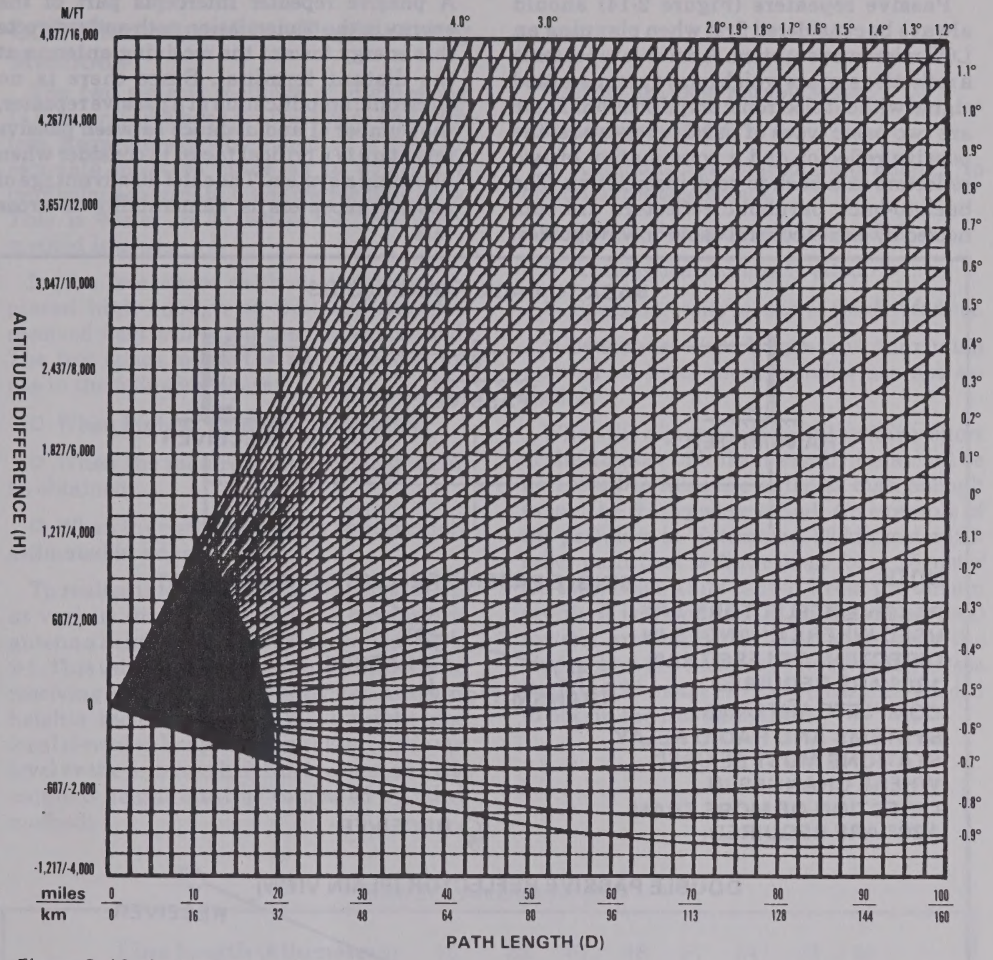


Figure 2-13. Antenna elevation angle.

Passive repeaters (Figure 2-14) should always be considered first when planning an LOS microwave system. A passive repeater is a reflective surface which relays a transmitted signal without electronic amplification. There are two basic types of passive repeaters: the passive reflector and a combination of two reflectors in a back-to-back installation. The back-to-back parabolic reflectors are connected by either coaxial cable or waveguides. A passive repeater intercepts part of the energy in the transmission path and redirects this energy toward the receiving antenna at the distant terminal. Since there is no electronic amplification at a passive repeater, the number of and distance between passive repeaters is a critical factor to consider when planning a system. The chief disadvantage of passive repeaters is vulnerability to cross talk.

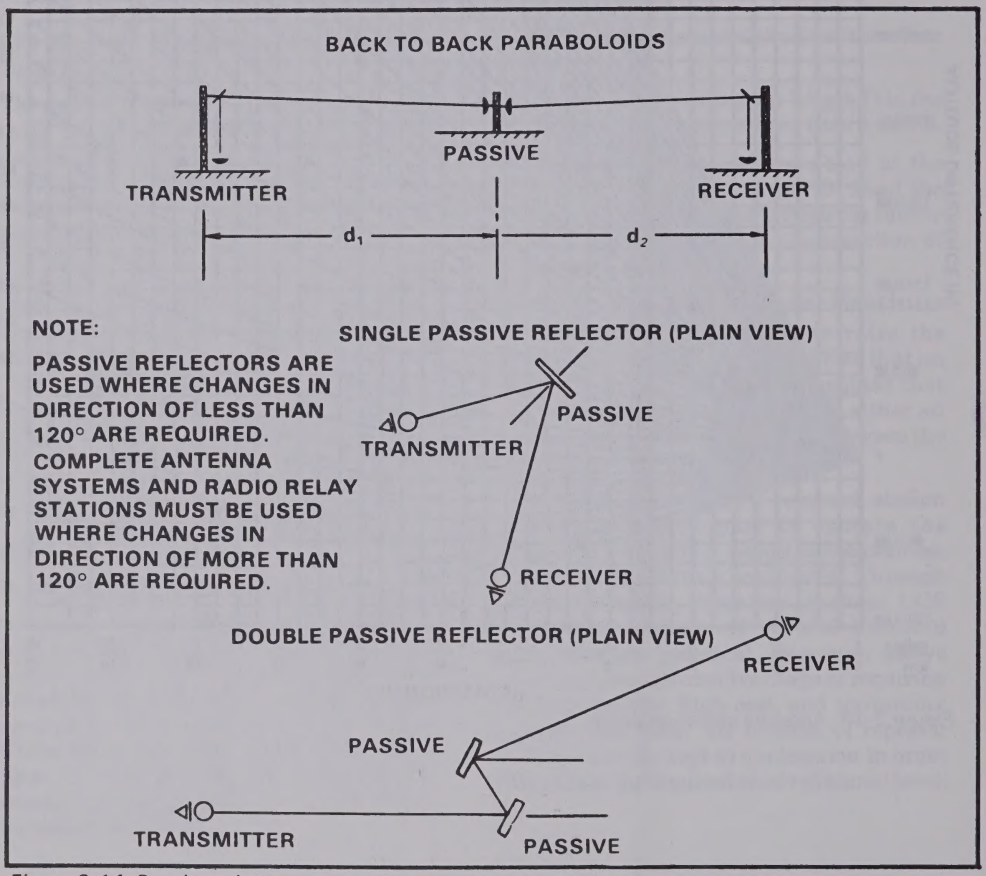


Figure 2-14. Passive microwave repeaters.

LOS Microwave Link Engineering Methods

The two general methods of engineering LOS microwave hops are free space and path loss. Regardless of which method is used, an estimate must be made as to whether a particular actual path meets the requirements. This is easier to do when the free space method is used.

In the free space method, antennas are placed high enough so that the expected received field will equal the free space field. The free space method is recommended for use in the following cases:

- When highest reliability is required.
- When the required antenna height can be obtained.
- When the path loss cannot be accurately estimated in advance.

To realize the free space field at 2000 MHz, at various distances over level terrain, the antenna heights required are shown in Table 2-1. This table assumes that transmitting and receiving antenna heights are equal. Antenna heights include antenna mast height and local elevation height. When the terrain is not level or the antenna heights are unequal, the required height must be computed by other methods.

Circuits are most reliable when:

- Links are short.
- Antennas are placed high enough to obtain a free space field.
- Fading due to terrain is avoided.
- Antennas are properly sited.
- Space diversity is used to combat fading.
- Maximum link length and maximum number of links recommended are not exceeded.

When the distance of the link is fairly short or the number of links is small, it may not be necessary to raise the antenna high enough to use the free space method. An example of the path loss is: Estimate a 32-kilometer (20-mile) path that is flat except for a 15-meter (50-foot) ridge at its center. From the terrain profile it is found that if 36-meter (120-foot) towers are used, the clearance over the obstruction is 6 meters (20 feet), which is less than the 23-meter (75-foot) clearance needed to obtain the free space field.

Table 2-1. Antenna heights.

Line length (kilometers)	19	32	40	48	57	64	72	80
(miles)	12	20	25	30	35	40	45	50
Antenna height (meters)	27	36	49	60	75	91	110	128
(feet)	90	120	160	200	250	300	360	420

□ Set up the maximum allowable path loss requirement for various numbers of links. Compare the requirement with the estimated actual path loss. Make a suitable allowance for the uncertainty of the estimate.

□ For maximum allowable path loss requirement, the steady-state conditions and the effects of fading must be considered. The minimum steady-state requirement is a normal path loss small enough to result in an estimated steady noise level of -38 db when the circuit in question is operated at a 0 db transmission level. The maximum amount of fading allowed is a loss small enough to meet 1 percent fading criterion.

□ It is sufficient to meet the steady-state requirement when space diversity is used effectively and impairment of service during deep fading is acceptable.

□ In other cases, the link should be engineered for a maximum of 1 percent fading and excessive fading should be avoided.

□ If extra losses caused by low RF power, extra lead-in cable, lower gain antennas, or similar situations are encountered, subtract the sum of the extra losses in db for the required values.

Section V. Tropo Transmission Paths

Transmission Paths

Planning considerations for tropo transmission paths differ from LOS paths due to the mode of propagation.

Tropo propagation requires high-power transmitters, high-gain antennas, and selective receivers. The antennas and receivers are arranged for dual diversity reception. Tropo systems use frequencies in the SHF range and the sites are located on high terrain to provide adequate earth clearance.

A tropo radio terminal consists of the equipment necessary for duplex operation mounted in a transportable shelter.

Antennas with parabolic reflectors are used with tropo to focus the radiated energy into a narrow beam. The antennas are located 100 wavelengths apart to satisfy the space diversity requirements. This distance will vary with frequency and with the types of scatter equipment and antennas used. Transmitted signals in relationship to the propagational path will affect the distance between diversity antennas.

Common Volume

The radio signal energy in the tropo mode arrives at the receiver antenna essentially by a scattering action. This is due to refraction from tropospheric turbulence clouds (blobs). A great leeway exists in the usable common volume, since blobs actually exist from the ground level up through the entire troposphere. Thus, the height of the tropo common volume can be varied by the angles of arrival and departure from the antennas with the lower limit controlled by the radio horizon.

The lower the common volume the better the scattering action because the radio energy arrives at the common volume with a smaller angle of incidence. The closer the common volume to earth the more turbulent is the atmosphere. The angle of departure from the transmitting antenna should be as low as possible while providing sufficient clearance above the horizon to clear the first Fresnel zone. In Figure 2-15, common volume A will not scatter the radio signal as effectively as common volume B.

Antennas and Orientation for Tropo Radios

Tropo antenna site selection is exceptionally important because high objects must be avoided. The angle and elevation angle of the main lobe should clear any foreground obstacles by at least 25 wavelengths (Figure 2-16). Raising the antenna will result in some gain for each wavelength of increase. This gain is apparent and progressive until the

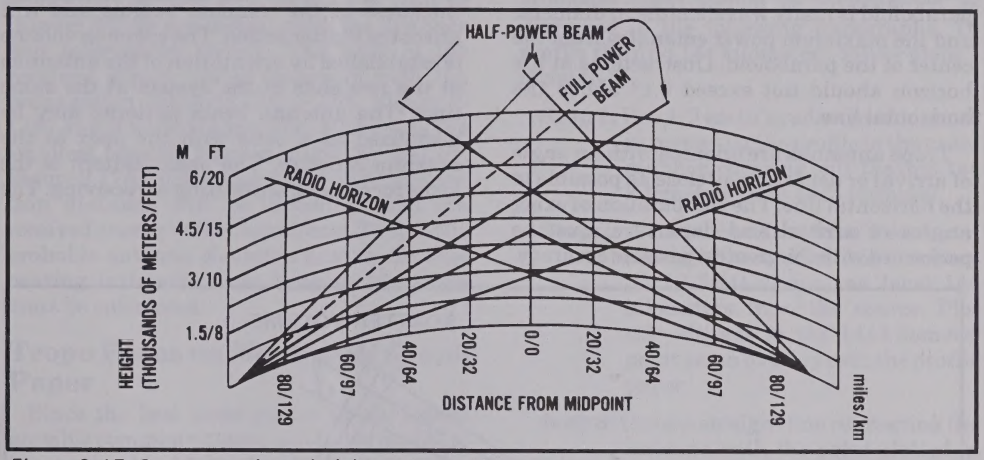


Figure 2-15. Common volume heights, tropo path.

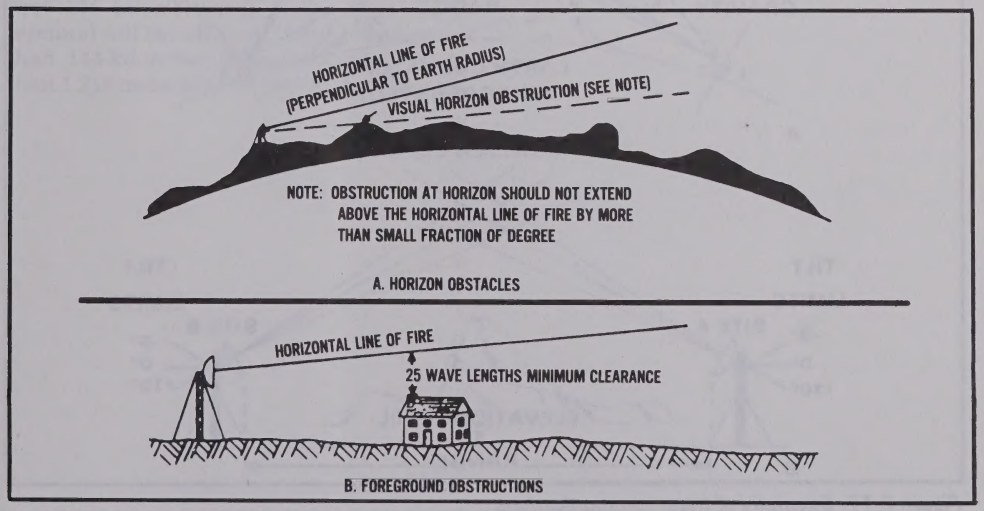

HORIZONTAL LINE OF FIRE
(PERPENDICULAR TO EARTH RADIUS)
VISUAL HORIZON OBSTRUCTION (SEE NOTE)
NOTE: OBSTRUCTION AT HORIZON SHOULD NOT EXTEND ABOVE THE HORIZONTAL LINE OF FIRE BY MORE THAN SMALL FRACTION OF DEGREE
A. HORIZON OBSTACLES
HORIZONTAL LINE OF FIRE
25 WAVE LENGTHS MINIMUM CLEARANCE
B. FOREGROUND OBSTRUCTIONS

Figure 2-16. Relation of obstacles to antenna LOS.

bottom of the paraboloid reaches approximately 20 wavelengths above ground. Above 20 wavelengths little or no additional gain is obtainable. Obstructions in the foreground may be cleared in this manner, since the paraboloid is many wavelengths in diameter and the maximum power emanates from the center of the paraboloid. Obstructions at the horizon should not exceed 0.1° above the horizontal line.

Tropo antennas are oriented with an angle of arrival or departure as close as possible to the horizontal line. The computation of exact angles of arrival and departure must be performed with the greatest possible accuracy. Locations of the terminals should be exact to the nearest minute of the latitude and longitude using true north as a reference. A very small variation in the angle of departure will produce a large change in the length and thickness of the common volume and will affect the scatter action. The common volume is established by orientation of the antennas at the two ends of the system at the same time. The antenna beam patterns may be visualized as a cone with the apex at the antenna reflector. The beam pattern is the same for either transmitting or receiving. The

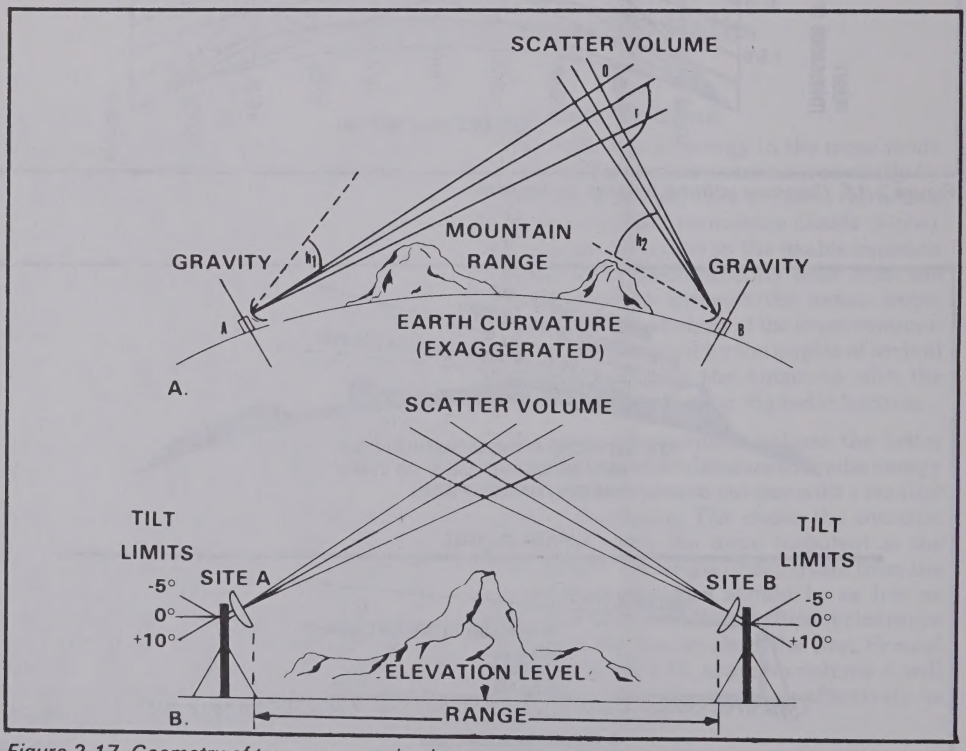


Figure 2-17. Geometry of tropo communications.

horizon angle is a line normal to the perpendicular antenna. The dotted lines (Figure 2-17A) represent the horizon angle. The propagation angle h_1 at site A is negative and h_2 at site B is positive. Therefore, the antenna tilt angles may be either zero, negative, or positive (Figure 2-17B) depending upon the distance and intervening terrain. The level of the received signal varies inversely with the propagation distance (AO + OB, Figure 2-17A) and the scatter angle (r). By having the smallest possible horizon angle (h_1 and h_2, Figure 2-17A), the scatter angle and propagation distance will be minimum and the received energy will be maximum. To find the probable antenna elevation angles, the true bearing (azimuth) lines between terminals must be calculated.

Tropo Paths on Nonlinear Graph Paper

Since the best tropo occurs at the lowest possible common volume, a detailed profile of the path should be drawn to determine whether or not strict horizontal transmission is possible. Usually, a detailed profile of the first 144 kilometers (90 miles) from each terminal will be sufficient. Any obstacle more than 144-kilometer distance must be more than 1,219 meters (4,000 feet) higher than the antenna to have any influence on the transmission path. Furthermore, the greater the distance from the terminal, the higher the obstacle would have to be to affect the tropo system. Presence of obstacles beyond the 144-kilometer point should be investigated as described in the following paragraphs. To profile the first 144 kilometers, follow steps 1 through 5:

Step 1: Use 4/3 earth's radius profile paper in preparing the profile in the usual manner, covering only the first 144 kilometers from each terminal.

Step 2: A horizontal line from a source at sea level would be 1,234 meters (4,050 feet) above sea level 144 kilometers from the source. Plot this altitude at the 144-kilometer point on an overlay over the profile paper.

Step 3: Draw a straight line connecting the antenna with the point plotted in step 2 above. This is the horizontal line of fire for the proposed antenna site.

Step 4: If this horizontal line of fire misses all obstacles within the first 144 kilometers, then the system can be established (line A, Figure 2-18).

Step 5: If the horizontal line of fire is blocked by an obstacle (line B, Figure 2-18), it can be adjusted to clear the obstacle by either of two methods:

- The antenna can be raised high enough to clear the obstacle (line C, Figure 2-18). This maintains the transmitting and receiving antenna beams as low as possible and the common value at the lowest possible altitude. This, in turn, produces the best scattering effect.
- If the obstruction extends above the horizontal line of fire further than it is practical to raise the antenna, you can raise the angle of fire enough to miss the obstacle (line D, Figure 2-18). This will throw the common volume off to one side of the path's midpoint. Unless the angle is excessive, the signal's slight deterioration will be less than it would be if the other end of the system angled its antenna to bring the common volume back to path center.

To compute the angle of fire required to clear an obstacle, follow steps 1 through 4:

Step 1: Subtract the altitude of the antenna from the altitude of the obstacle. This gives the altitude difference.

Step 2: Add 18 meters (60 feet) to the altitude difference, which corrects for first Fresnel clearance over the obstacle. A general figure that will provide sufficient clearance is 18 meters—if any doubt exists, exact computation of the Fresnel clearance should be made.

Step 3: Divide the corrected altitude difference in step 2 above by the distance to the obstacle (in meters or feet, depending on which unit of measurement is used). This gives the tangent of the angle of fire required to clear the obstacle.

Step 4: For example, the right-hand profile in Figure 2-18 shows that the antenna is 610 meters (2,000 feet) above sea level and the obstacle is 48 kilometers (30 miles) away from the terminal and 823 meters (2,700 feet) above sea level. Subtracting the antenna altitude from the obstacle altitude and adding the clearance factor of 18 meters results in a corrected altitude difference of 232 meters (760 feet). The distance, 48 kilometers equals 48,280 meters (158,400 feet). Then 232 meters divided by 48,280 meters equals 0.00479, which is the tangent of the angle of fire. The trigonometric tables show that the vertical angle of fire necessary to clear this object is 0° 16′ 46″.

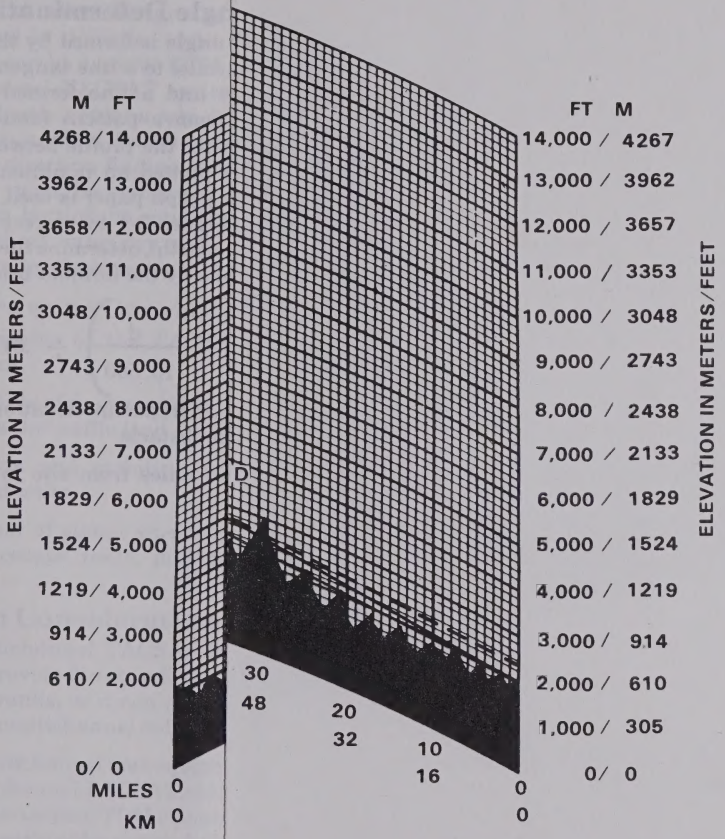


Figure 2-18. Sample

Step 4: If this horizontal line of fire misses all obstacles within the first 144 kilometers, then the system can be established (line A, Figure 2-18).

Step 5: If the horizontal line of fire is blocked by an obstacle (line B, Figure 2-18), it can be adjusted to clear the obstacle by either of two methods:

- The antenna can be raised high enough to clear the obstacle (line C, Figure 2-18). This maintains the transmitting and receiving antenna beams as low as possible and the common value at the lowest possible altitude. This, in turn, produces the best scattering effect.
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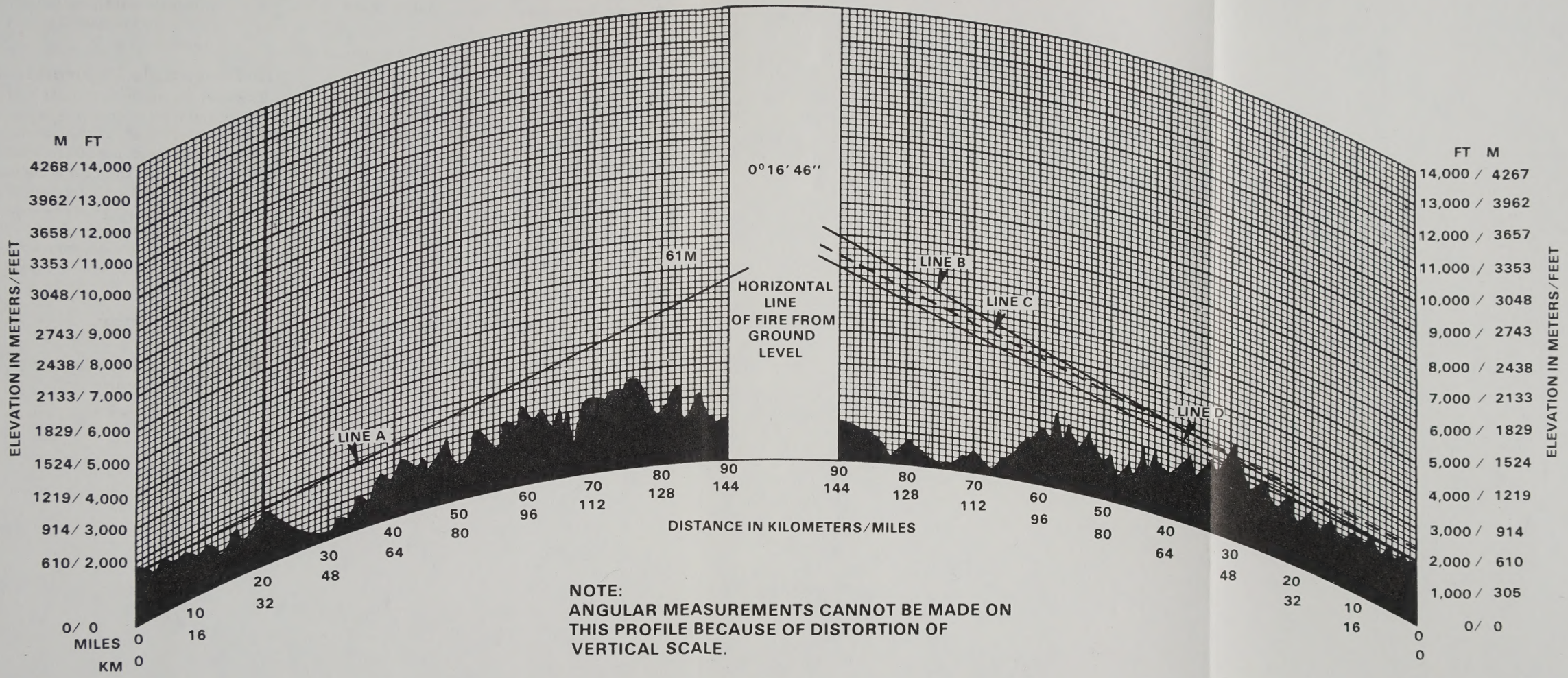


Figure 2-18. Sample Profile, tropo path.

To determine if an obstacle beyond the 144-kilometer (90-mile) point will have any effect on the transmission path, follow steps 1 through 5:

Step 1: Determine the distance of the obstacle from the antenna.

Step 2: Subtract the altitude of the antenna above sea level from the altitude of the obstacle above sea level.

Step 3: Use the formula for distance and height (D=V2h). Substitute the distance of the obstacle from the terminal for D in the formula and solve the equation for h. This gives the height above sea level of the horizontal line of fire at the distance of the obstacle.

Step 4: If the result of step 3 is greater than the result in step 2 above, then the obstacle will have no effect on the transmission path.

Step 5: If the result of step 3 is less than the result in step 2 above, then the obstacle will affect the transmission path, and remedial action must be taken.

Horizon Angle Determination

The horizon angle is formed by the intersecting line parallel to a line tangent to the earth's surface and a line formed by the center of the beam's pattern (dotted line, Figure 2-16). After the profile between both sites has been plotted on nonlinear graph paper (if linear graph paper is used, refer to the chart in Figure 2-9 to correct for the curvature of the earth), determine the horizon angle of each site by the formula below.

$$= \left(\frac{\Delta H}{d(5280)} - \frac{d}{10,560} \right) \div .01745$$

ΔH = Effective difference in elevation of site and nearest obstacle.

d = Distance in miles from site to nearest obstacle.

Section VI. TACSATCOM Systems

Locations

Multichannel TACSATCOM does not require the use of prominent terrain for the location of ground terminals. LOS must only be maintained with the satellite which will ordinarily remain stationary in relation to the earth's surface. The ground terminals can be located in defilade, and natural terrain features can be used for ECM masking. The multichannel TACSAT systems use a very narrow beam antenna which affords some protection against detection of the terminal by radio direction finding techniques. If the systems must be reconfigured because of changing battlefield conditions, it can be done without extensive path profiling and coordination of relays.

Factors to be Considered

Capabilities of the TACSATCOM radio equipment.

Capability of the associated mux equipment to handle the traffic load.

Location and mobility requirements of supported units.

Selection of signal sites to provide accessibility, escape route, and good defensive positions.

System Considerations

A multichannel TACSAT system can be used to provide direct radio linked communications trunks, or it can function as a radio link in a multichannel cable system.

The multichannel mux equipment used with the multichannel TACSAT radios is compatible with the tactical TDM equipment currently deployed within the corps/division area.

The separation of the radio terminal from the mux equipment is explained on page 2-1.

Techniques of Site Location

Factors such as physical security determining the earth terminal azimuth, antenna elevation angles, positioning the vehicles, and accessibility to the site must be considered when selecting a TACSAT signal site.

The CSPE will determine the grid coordinates of the selected site during the planning stage of a mission. This is also the time to choose an alternate site. Earth terminal azimuth and antenna elevation angle are normally furnished by GMF manager.

□ The grid coordinates are determined using a military topographic map and a protractor (FM 21-26).

□ The methods of selecting a tentative relay site are explained on page 2-2.

□ The earth terminal azimuth and antenna elevation angles are determined as follows:

- Determine the grid coordinates of the earth terminal.
- Determine the ground trace coordinates of the satellite from updated ephemeris data.
- Calculate the longitude and latitude differences between the earth terminal and ground trace coordinates of the satellite.
- Refer to Figure 2-19 for determination of the azimuth, for example:
  - —Estimate an earth terminal is located at 158 °west longitude and 21.5° north latitude.
  - —The satellite is located at 135° west longitude and 0° latitude.
  - —Longitudinal separation of the satellite and the earth terminal is 158° - 135° = 23°.
  - —The intersection of 23° longitude difference and 21.5° latitude is at 131° azimuth arc.

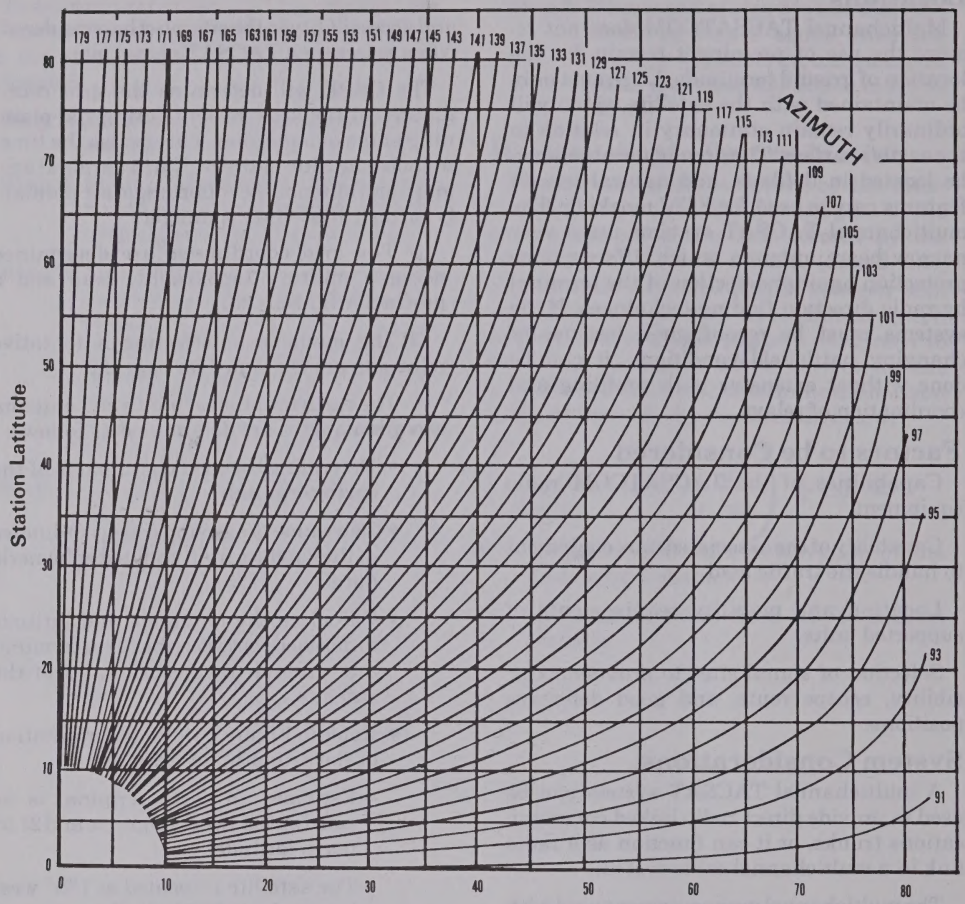


Figure 2-19. Azimuth determination chart for earth terminal to geostationary satellite.

Table 2-2. Adjustments for azimuth determination.

Satellite Direction From Earth Terminal	Azimuth Adjustment
East and South	None
West and South	Subtract azimuth selected on Figure 2-19 from 360° to obtain actual azimuth.
East and North	Subtract azimuth selected on Figure 2-19 from 180° to obtain actual azimuth.
West and North	Add 180° to azimuth selected on Figure 2-19 to obtain azimuth.

— As no azimuth adjustment is required (Table 2-2), the earth terminal to satellite azimuth is 131°.

—The earth terminal antenna elevation angle can be determined by use of the graph in Figure 2-20. Estimating the same earth terminal location; that is,158° west longitude and 21.5° north latitude, and the same longitudinal difference of 23°, the antenna elevation angle will be 53°.

The above information derived by the CSPE must be passed on to the ground terminal operating crew before they depart for the selected site location.

Final Site Selection

Upon arrival at the selected site location, it will be necessary for the ground terminal crew to select the specific site upon which to position the vehicles. The selected site should conform to the following requirements:

□ A relatively flat area is preferred. The grade of the slope must not exceed 5°.

□ No natural or man-made obstacles between the antenna and the satellite.

□ A relatively clear area greater than 12 meters (40 feet) in diameter.

□ The antenna should not face toward nearby electric noise sources: power lines, electric generators or radar transmitters.

□ The soil condition can support the weight of the equipment and provide adequate holding for the tie-down anchors.

□ The crew can proceed to set up and align the antenna when the above conditions have been satisfied.

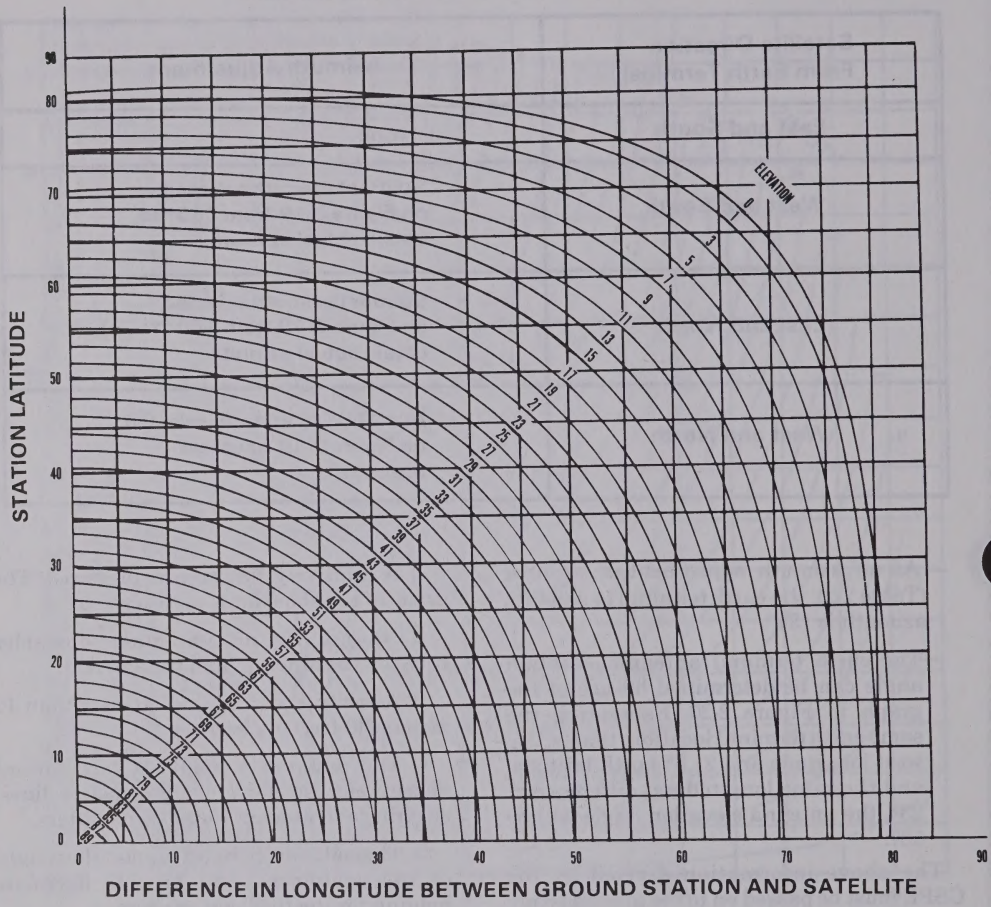


Figure 2-20. Elevation angle determination chart for earth terminal to geostationary satellite.

Section VII. Systems Reliability

Estimating Systems Reliability

There are many factors other than equipment failures to be considered in estimating the reliability of a multichannel system. These include transmitter power distances between stations and receiver sensitivity. Other factors, such as reflected or refracted signals, fading, and seasonal changes can affect reliability. Many of these variables may be controlled by careful site selection, use of proper equipment, and allowances for fading. System reliability can be reduced to the ratio of usable circuit time to total circuit time. The circuit is usable when traffic can be passed without errors. For voice telephone traffic, the percent of reliability required is 98 percent and for digital data traffic, 99.9 percent is required. Two major factors affect system reliability—the propagational support actually received and the equipment reliability. Equipment is a large factor in any discussion pertaining to system reliability, but equipment is left out because on important systems there is sufficient backup equipment to prevent system outage due to equipment failure. Having dropped equipment failure, system reliability depends on effective transmitted power, total path losses, median receive signal level, signal level required for threshold, and fade margin. Signal level required for threshold is a function of receiver design. These factors, however, can be significantly affected by radiation and debris from a nuclear detonation.

A signal will be affected by the receiver antenna gain and the transmission line loss between the antenna and the receiver. For a received signal to be usable, it must be stronger than the receiver noise level. Manufacturers of the receiving equipment determine a signal level of modulation used and the receiver design. This level is called the threshold level. It represents the lowest signal level that can be used. A received signal may be only barely above this level, but satisfactory reception will result if there is no fading. Because fading lowers the signal strength, a strong signal is required under normal conditions so that the signal will remain usable under fade conditions. The difference between the field strength of the level normally received and the threshold level is called the fade margin. Fade margin is the difference between the median receive signal level and signal level required for threshold. That is to say the difference between the level of the transmitted RF signal in the area of the receive antenna and that signal level required at the receiver input to produce a noise free output. Fade margin and reliability are directly related. As shown in Figure 2-21, the AN/GRC-144 shot fade margin would be MSC (-59 db) - threshold level (-91 db) or 32 db's. A 32 db fade margin would provide a 99.99 percent path reliability nondiversity. Effective transmitter power and receiver threshold are both functions of design. Total path losses can be controlled to some extent, therefore, each path must be investigated to ensure LOS vision between antennas and good first Fresnel zone clearance. Since path losses increase with both path length and frequency, path length should be limited to near 25 miles at the higher microwave frequencies.

The ETP minus the total path losses equals the median receive signal level; that is, the average level of the transmitted signal in the area of the receive antenna. The median receive signal level will vary depending on fade conditions such as time of day or time of year. Using the AN/GRC-144 shot in Figure 2-21 the median receive signal level would be 79 db to 138 db or -59 db.

Threshold signal level is that level of signal necessary to overcome receiver noises. The threshold signal level is that level of signal at the receiver input necessary to produce a noise free output. The threshold level of a receiver is a function of design. The threshold level of Radio Receiver R-1467/GRC-144 is -91 db. The field strength for any radio site may be calculated within ± 5 db. Do this by using

information from the equipment manual and data taken on the individual links of a multichannel system.

A simplified method to obtain ETP is the sum of the transmitter RF power output in db plus the gain of the transmit and receive antenna minus transmission line losses. Transmitter power output is fixed within a plus or minus 1 db. Antenna gain depends on antenna size and frequency. Antenna gain increases as frequency increases or antenna diameter increases. (One or the other constant, to a certain point.) Increases above that certain point will cause a loss in effective transmitted power. The sum of the transmission line losses depends on the type of line used. Losses are higher for coaxial line than waveguide lines. Systems using waveguide transmission lines would have a total loss of approximately 5 dbs. A microwave shot (25-30 miles) using the Radio Set AN/GRC-144C transmitting at 4.7 GHz would have an effective radiated power of approximately 79 dbm. Formula ETP = P_T - LL_T +G_T.

The radio frequency energy (power) falls off as the square of the distance between the transmitting and receiving antennas increases. EXAMPLE: At 2 miles from the transmit antenna, the radio frequency energy is 4 times less than at one mile from the antenna; at 4 miles, it is 16 times less. From Figure 2-21, you are able to determine the approximate basic free space losses on a microwave radio path; propagational losses vary as frequency varies. Using the 25-mile path above (AN/GRC-144) and the equation L_{fs}=96 + 20 log F_{MHz} + 20 log D $_{mi}$,the path losses for the shot would be 197 db's.

Radio equipment used in multichannel systems operates best with one section of coaxial cable between the antenna and radio. Additional sections of coaxial cable increase transmission line loss, thus the antenna must be located as near to the equipment as possible. Using two or more sections of coaxial cable reduces the output signal by more than 50 percent.

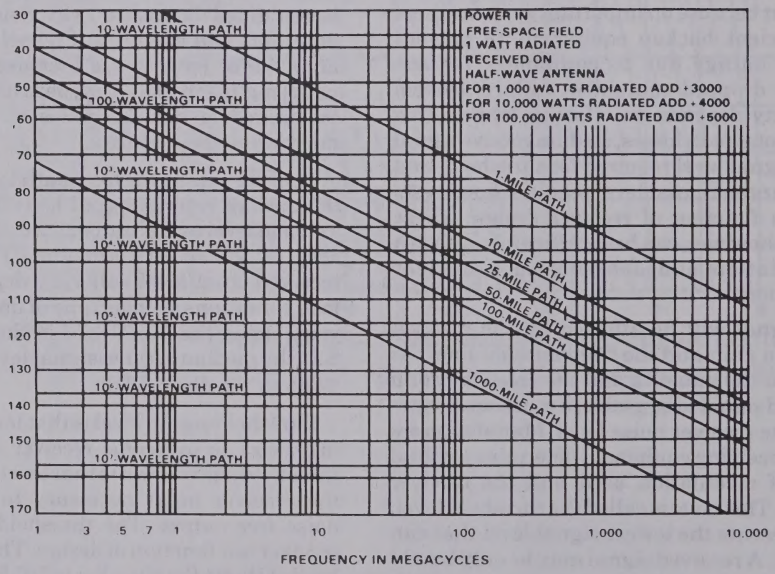


Figure 2-21. Attenuation of power with frequency and distance.

Acceptable Reliability

Reliability is determined by the percentage of time the signal strength at the receiver is above a selected level. This level is to be expected 90 percent of the time and will depend on receiver characteristics and fade conditions. Where signal strength equals threshold level, outage time would be 10 percent and not acceptable. No multichannel system should be planned to operate at the receiver threshold level since the slightest fade will result in system outage.

To increase reliability, plan links so that the signal level is higher than the threshold level of the receiver and will absorb fading. For example, if the received field strength at the receiver is -10 db and the receiver threshold level is -50 db, the -40 db gives a reliability of 99.99 percent. The relationship between reliability and fade margin is usually given in applicable technical manuals for engineering reliability. Path attenuation is usually the greatest source of fading. Therefore, where low reliability is acceptable, relay stations may be spaced further apart.

In calculating reliability, the simplest and safest method is to assume that outages in the various links will not occur at the same time. For example, in a system of 5 links with an efficiency of 99 percent for each link, it is safe to estimate that each will be out 1 percent of the time. The total outage time for the entire 5-link system will be 5 percent and the system would have reliability of 95 percent. As the number of links increase, the likelihood of more than one link being out at the same time increases and will reduce reliability.

Factors Increasing Range of Reliability of VHF, UHF, and Microwave Multichannel Systems

There is no simple method of evaluating the effects of nuclear weapons employment nor of weather or terrain conditions on multichannel systems. However, the effect of many factors can be evaluated. When installation of radio links beyond the radio LOS is necessary, the items described below will improve performance.

Proper antenna orientation (excluding TACSAT). Transmitting and receiving antennas should be rotated (changed in azimuth) to reduce the effects of reflected signals caused by rough terrain features in their vicinity. The antennas at each end of the circuit should be rotated alternately until the best orientation is obtained between them. However, sharp terrain features may be used to provide usable indirect radio paths when both transmitting and receiving antennas are properly oriented. Normally, direct paths are better; but, in some cases, indirect paths will have to be used.

Radiation of strong signals.

□ Multichannel systems should use the minimum amount of power required for good reception but enough power to overcome fading. Low power will minimize adjacent and cochannel interference within a multichannel system. It will also reduce the amount of interference between adjacent or interconnected multichannel systems and lessen the possibility of enemy interception.

□ Using high-gain receiving antennas is the same as increasing transmitter power.

□ Losses between the transmitter and the antenna can be minimized by using a high quality transmission line. This line should be as short as possible and properly matched at both ends.

Use of lower level signals at receiver.

□ High gain antennas, properly oriented and situated away from noise sources, will provide better reception than simpler types. Local sources of interference, such as high voltage transmission lines, ignition systems, or other electrical equipment must be avoided to reduce noise. Nearby communications

equipment may also generate spurious signals and increase the background noise level. Adjacent channel or cochannel interference can also determine the lowest useful signal at the receiver.

□ The received signal must compete with noise generated within the receiver. High-quality receivers located away from interference sources, using high-gain antennas and short transmission lines, will provide the best signals.

□ Space diversity can increase reliability when signals are weak.

Factors Affecting Reliability of Tropo Systems

No one factor affects the reliability of tropo systems. Some factors that are given consideration are the proper use of propagational support, site planning, and utilization and maintenance of equipment. The factors described below will help increase the reliability of tropo systems.

In tropo, the amount of received signal depends on the number of turbulences illuminated in the common volume of the transmitting and receiving antenna. This is called the scatter volume. The received signal is low level and is affected by seasonal variations and fading due to the multiple paths from the scatter volume. Although the signal level is constantly changing, complete fadeout will not occur. To compensate for the low efficiency of the scatter volume, the incident power must be high. This is accomplished by using high-power transmitters and high-gain antennas. The sensitivity of tropo receivers must be very high. An increase in the transmitter output power will give measurable system improvement.

Besides forward scatter, other modes of propagation can be used with tropo equipment. When used properly, these modes will provide reliable communications where the scatter mode will not or is not desired. These other modes are direct LOS and ducting.

□ Direct LOS propagation along the terminal intersecting line allows low loss communication between terminals.

□ Ducting is a condition in which stratified layers act as a waveguide. Radio waves may be conducted over great distances.

The following are some engineering techniques to improve reliability:

□ Installing larger parabolic reflectors in the antenna systems will increase gain. In tropo systems, aperture to medium coupling loss is encountered and increases as the antenna diameter is increased. Initially a larger antenna will give an overall system gain. As the antenna gets larger, the AMCL may overcome the gain, thereby degrading the system.

□ Increasing the FM deviation ratio, where possible, will also improve gain.

□ Dual or triple diversity can be used.

□ Accept a lower short-term reliability. Reduction of the short-term reliability to 96 percent would increase the system reliability margin by approximately 2 dbs. However, you must assume more frequent short-term outages will occur. Note that system reliability takes into account outages of longer duration.

□ Receivers with a noise figure of +8 db would give an effective increase of 4 dbs in the reliability margin.

□ Reduce the telephone channels in a system. This will result in an improvement in db.

□ Use companders on each channel of the system. A compander is a combination of a compressor at one point in a communications path for reducing the volume range of signals, followed by an expander at another point for restoring the original volume range. Its purpose is to improve the signal-to-noise ratio. This is probably the most effective and economical method of improvement.

System reliability also depends on equipment reliability and the added expense of extra equipment usually can be justified. However, just having the spare equipment is not sufficient. It must be made an integral part of the system and connected so that if one piece of equipment fails a similar item of equipment automatically takes over. In an anticipated nuclear environment, however, consideration must be given to disconnecting some equipment from the system. This must be done because of the electromagnetic pulse, which could upset or damage all unprotected equipment. Fortunately, in tropo the fine lobing patterns of the propagated wave are lost in the scattering process, and it is possible to provide simultaneous transmissions from two separate antennas. With this system, the failure of an item of equipment in either the primary or backup systems causes only a minor effect on the received signal. The multiplexing equipment is normally not provided in duplicate and, therefore, cannot be switched over in case of a failure. However, this equipment has very high reliability.

Section VIII. Power Generator Sets

Generators

In today's flexible/mobile signal units we will rarely find a convenient wall receptacle to plug our communications equipment into. Instead of a wall receptacle, we have a power generator set to provide the necessary electrical power to operate our communications equipment. The generator sets are normally mounted in trailers which are towed behind the vehicle carrying the communications equipment. In this manner, a multichannel crew can move into a site location without having to depend on someone else to provide power for the multichannel van.

TOE allowances designate a particular generator set for each particular multichannel van. However, in a combat situation you may not always have that particular generator set.

If your assigned generator set is destroyed or inoperable, to select another generator set which will provide the necessary power to operate your van, you must know:

□ The voltage required to power your particular van; such as, 115 V AC, 60 Hz.

□ The total wattage your van will draw; such as, 5 kw, 10 kw.

NOTE: The above information is contained in the TM provided with your van.

□ Your vehicle is capable of towing the selected generator set.

□ The TM supplied with each generator set will tell you the voltage, Hz, and wattage output of that particular generator set. With this information you can tell if it will meet the requirements of your van.

As a multichannel equipment operator, you are also required to operate and perform organizational maintenance on the power generator set supplied with your multichannel van.

The TM supplied with your generator set will explain all the details for operating and maintaining your generator set. The instructions must be followed. If you take shortcuts or neglect your generator set, it may become inoperable and that means your communications equipment ceases to function.

Methods of Grounding

One very important last word on your generator set, NEVER START YOUR GENERATOR SET WITHOUT FIRST PROPERLY GROUNDING IT. There are three common methods used to establish a good ground.

- A ground rod driven 2.44 meters (8 feet) into the ground.
- A ground pipe of 3/4-inch copper or steel, driven 2.44 meters (8 feet) into the ground. An existing pipe may be used in an emergency.
- A metal plate .84 square meters (1 square yard) buried in the ground to a depth of at least 4 feet.

Secure a ground strap which must be at least No.6 AWG copper wire bolted or clamped to the ground rod, metal water pipe, or metal plate. Connect the other end of the ground strap to the generator set ground stud.

For information on grounding techniques in various adverse terrain and climatic conditions, see Chapter 6.

Chapter 3

Radio Frequency Management and Selection

Section I. Frequency Management

General

Only a portion of the radio frequency spectrum is available for use by the tactical multichannel communications systems. The radio frequency spectrum extends from 3 kHz to 300 GHz and is internationally controlled. The nations of the world meet periodically to permit equitable sharing of the spectrum on a worldwide basis for the mutual benefit of all. Frequency management down to US Army Division is discussed in the following paragraphs.

International

The ITU, a specialized control agency of the United Nations, is the international frequency manager. This group meets periodically to make agreements for regulations on use of the radio spectrum. They also establish standard methods and procedures to minimize interference. Additionally, most ITU countries impose their own control measures.

These regulations specify in detail the operation of international communications and frequency allocations.

The world is divided into three regions for the purpose of frequency allocations. According to agreements, the service may be the same in all regions or vary between regions. These allocations are used throughout the world.

The International Frequency Registration Board, which is a working group of the ITU, maintains a register of frequency assignments in the international frequency list. To ensure protection of frequency assignments, all United States registrations are made through the IRAC.

National

Within the United States and its possessions, the authority and procedures used to manage radio frequencies were established by the Communications Act of 1934. The Act established separate control procedures for government and nongovernment users.

The IRAC advises federal government departments on radio operations and assigns radio frequencies to federal government users.

The FCC regulates all nonfederal government radio communications and coordinates with the IRAC to avoid mutual frequency interference.

Department of Defense

The DOD local frequency management is handled by the J/FP of the MCEB. Neither the board nor the panel has executive status. MCEB serves as an advisor to the JCS.

□ The MCEB assists in preparing the coordinating joint directives and/or agreements in various signal activities, including frequency allocations and assignments.

□ The J/FP of the MCEB coordinates, allocates, and assigns frequencies for the military departments. It also coordinates with other military communications boards and committees as required.

□ Each military department has its own staff for planning and administering the use of the radio frequency spectrum.

The DOD uses a large computer facility to determine the potential interference of existing or proposed spectrum assignments.

Continental United States and Overseas Commands

Within CONUS, the office of the Director of the Telecommunications Command and Control obtains frequencies from the IRAC for CONUS Army commanders. This office authorizes frequencies and call signs for CONUS tactical and training requirements. It also coordinates with the IRAC and FAA to prevent interference.

The J/FP of the MCEB coordinates frequency assignments for use between overseas commands or between overseas commands and CONUS.

Department of the Army

One of the major users of the radio frequency spectrum is DA, and it has a vital interest in frequency management. It must share the spectrum with the other military services, government departments, and civil operations. The focal point for staff advice and coordination of all Army signal activities is the office of the Director for Telecommunications Command and Control. This advice and coordination includes the assignment, allocation, and control of Army frequencies. It also includes the negotiations for new frequencies to meet ever increasing requirements.

Corps and Division

Frequency control is the responsibility of the corps signal officer and the division signal officer. The corps signal officer is responsible for providing frequency support to all units of the corps. This includes:

□ Representing the corps at frequency conferences of higher headquarters.

□ Coordinating with adjacent and subordinate units.

□ Coordinating with the corps area frequency coordinator as required.

□ Preparing SOI items for the purpose of:

- Allocating frequencies to divisions.
- Allocating call signs.
- Assigning frequencies and call signs to corps headquarters and corps subordinate units.

□ Resolving interference problems.

□ Maintaining records of all frequency assignments within the corps area.

□ Receiving, processing, and forwarding radio frequency requirements for all signal operations in the corps area.

Multichannel requirements will usually exceed the available channels, particularly in areas with extensive television and aeronautical facilities in use. The ABM plan can be used to obtain maximum use of available frequencies. Multichannel frequencies must be controlled at all levels. Assignments of frequencies may be decentralized, but frequency requests must be forwarded to the corps frequency branch.

Multichannel frequencies are obtained from the corps SOI frequency list.

Multichannel frequency control and assignment procedures are as follows:

□ Divisions submit their plans to the corps frequency branch. The plans, in system diagram form, identify and locate terminals and relays. The grid coordinates for each are given and hill numbers are given where possible.

- Upon receipt of multichannel system plans, the corps signal officer plots all systems on a situation map and assigns frequencies using various multichannel system assignment techniques.
- After units receive their frequency assignments, coordination is conducted between the unit concerned and the corps frequency branch.
- All frequency requirements of units assigned or attached to a military post are submitted to the post frequency control officer who normally works in the office of the post signal officer. The post frequency officer will make necessary assignments from the assigned pool of frequencies for local use. If the pool of frequencies is not adequate to fulfill the request, the frequency officer will forward the request to the local area frequency coordinator. He will, if necessary, forward it to the J/FP in Washington, D.C., for action. Frequency assignments are then sent back down through the chain of command to the post frequency officer for control and assignment.

□ If the availability of frequencies permits, sublists of frequencies may be prepared at corps level and allocated to the subordinate units. Acting for the division signal officer, the division radio officer assigns the frequencies to each system in his respective area. This is accomplished by using the most effective techniques possible. Upon implementation, the complete multichannel plan must be forwarded to the corps frequency branch.

In the MSE system, the SCC s assigned to corps and division will provide automated system management and control tasks which include:

- LOS frequency management.
- Terrain analysis and path profiling.
- System activation and reconfiguration.
- Generation of radio net call signs.
- Preparation of the SOI.

These SOIs are reproduced at a separate facility which is not part of the SCC, for distribution in the corps.

Section II. Frequency Selection

Methods of Frequency Selection

The methods of frequency selection depend on the kind of equipment used and the communications network. The method used for each item of equipment is described in the TM covering that equipment.

Procedures for using the two-block method for assignment of frequencies to a simple, isolated route and the ABM method for assignment of frequencies to a complex system are outlined below. Both methods may be used for LOS equipment in multichannel systems.

Procedures for using the double ABM and XY methods for assignment of frequencies are also outlined below.

Interference Between Transmitters and Receivers

The purpose of any frequency plan is to minimize the effects of interference. With a radio set operating full duplex, the transmitter power is usually many times greater than the power of the received signal. The receiver must be able to reject the transmitted signal and select the weak signal to which it is tuned.

A receiver must be separated from the transmitter (Figure 3-1) by distance (Figure 3-1) or by frequency spacing (Figure 3-5) in order to accomplish effective rejection of a transmitted signal.

Cross polarization can be used (Figure 3-2) to reduce the required frequency separation.

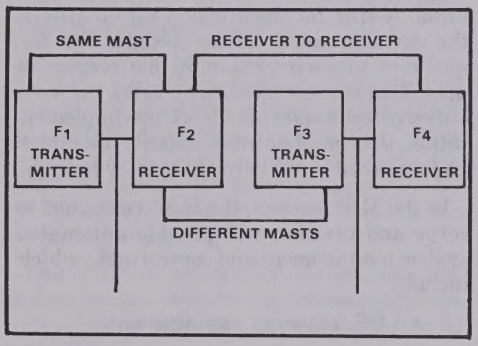


Figure 3-1. Transmitter and receiver separation.

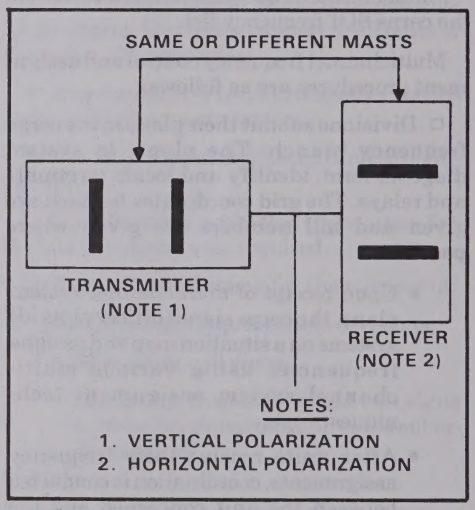


Figure 3-2. Cross polarization.

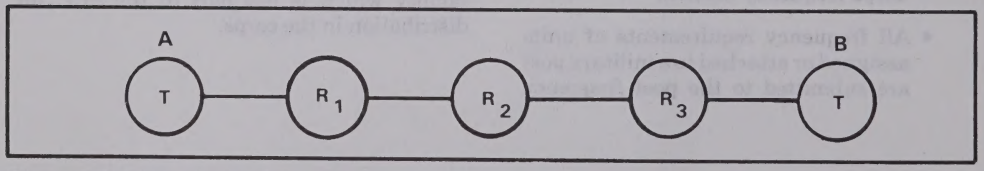


Figure 3-3. Simple isolated system.

Two-Block Frequency Assignment Plan

The two-block plan is used for simple isolated systems. For example, a system may consist of two terminals and three repeaters (Figure 3-3) with the radio sets operating between 200 MHz and 300 MHz.

Arrange the frequencies in a numerical sequence. Divide the frequencies equally into two lists (blocks). Separate the highest frequency in block I and the lowest frequency in block II. To determine the amount of separation, refer to the TM for the particular type radio set being used.

Assign transmitting frequencies beginning at terminal A. Then, alternately, select a frequency from block I and then block II (Figure 3-4). When this is completed, assign frequencies in the same manner from B to A (Figure 3-5).

Make certain that minimum required receiver-to-receiver separations are maintained at all sites where two or more receivers are located. For this reason, frequencies from a specific block may not always be assigned consecutively.

The two-block plan can also be used for a simple parallel system. Tangent systems from any site in the parallel system to other sites may also be established. This is possible because from any site in the parallel system, all transmitter frequencies are from one block and the distant station could transmit on the opposite block. The two-block plan does not provide for alternate routing or operating between three different sites. This is done by using the six-block (ABM) plan.

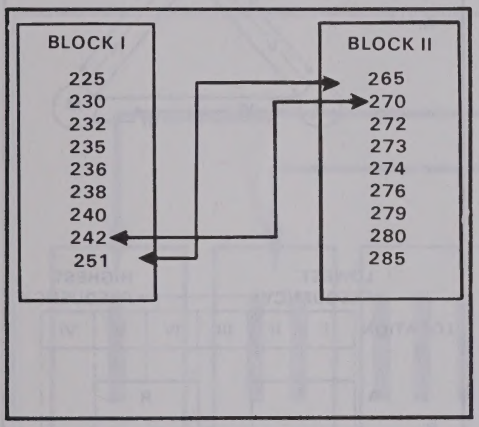


Figure 3-4. Frequencies divided into two blocks.

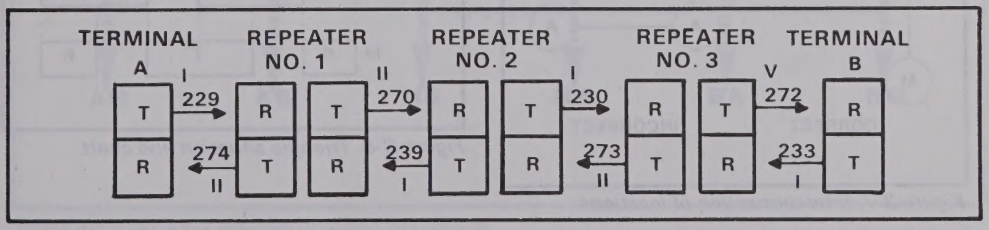


Figure 3-5. Two-block frequency assignment.

ABM Frequency Assignment Plan

The ABM plan is used for a complex system where there are two or more transmitters and receivers at the same location.

Using the ABM plan, designate each site with the letter A, B, or M (Figure 3-6). Be sure that sites with the same letter are not interconnected (Figure 3-7). Following this rule, location A can establish radio links with locations B or M but not with another A.

Considering all possible radio links, a triangle can be drawn as shown in Figure 3-8A. Radio sets used in multichannel systems do not require transmitter-to-transmitter separation. Therefore, all transmitter frequencies at one location can be taken from the same block.

Considering transmitter frequencies only, six groups or blocks of frequencies are required for the triangle (Figure 3-8B). These blocks of frequencies are numbered from I through VI. Relative to location A, I and II are the transmitting frequencies and IV and V are the receiving frequencies.

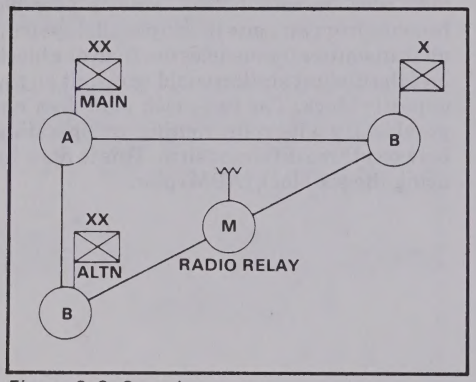


Figure 3-6. Complex system.

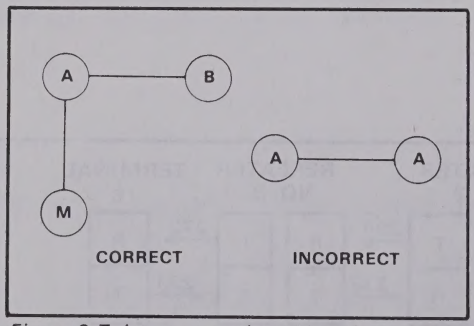


Figure 3-7. Interconnection of locations.

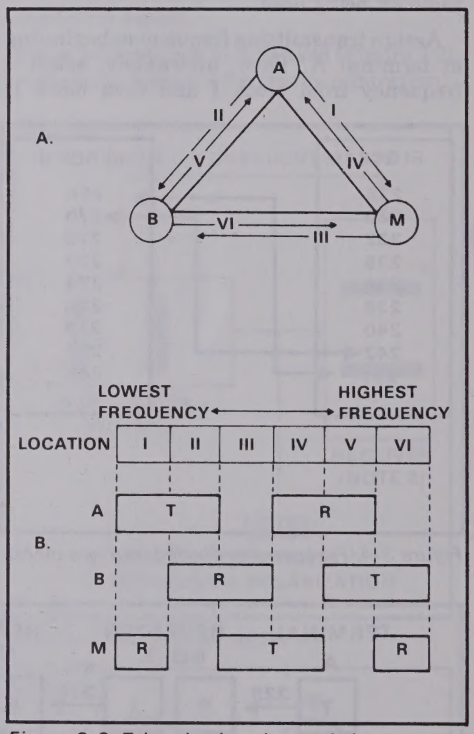


Figure 3-8. Triangle situation and chart.

Analyzing the situation in order to set up a system between A and M, the transmitter frequencies at A must be from block I and the receiver frequencies at A must be from block IV. Each system has a designated block from which the frequencies are taken (Figure 3-8B). To set up a system from B to M, find the block where B transmits and M receives. In this case it is block VI (Figure 3-8B). Now, the frequency separation required between the transmitter and receiver must be applied to the blocks of frequencies (Figure 3-9).

Frequency separation between the receiver and transmitter is different for each type of radio. To determine the amount of separation needed, refer to the TM for the particular type radio set being used.

Considering the six transmitter frequencies from the triangle situation, Figure 3-10 shows that six blocks of frequencies are required. Also considered are the necessary separations required between the blocks. Now, it is necessary to determine the number of frequencies required in each block. To accomplish this, an analysis must be made of the system requirements (Figure 3-10).

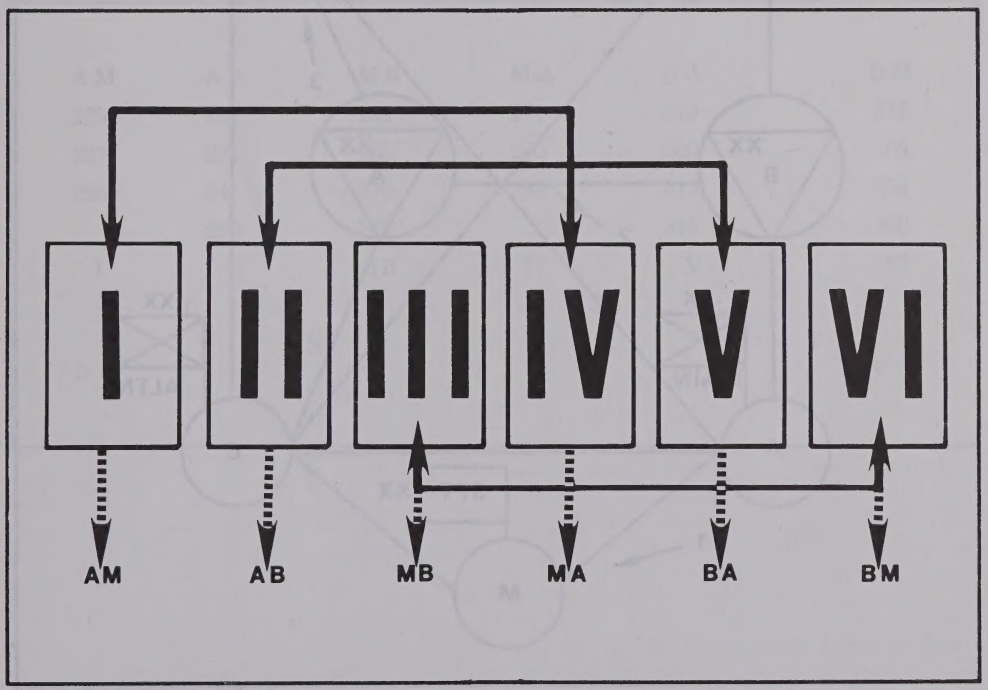


Figure 3-9. Frequency selection (transmit and receive).

From Figure 3-10, it can be seen that three transmitter frequencies are required for the A to M shots. Thus, a minimum of three frequencies are required in block I for A to M. Continue the analysis of the system. Table 3-1 shows the requirements for the entire system.

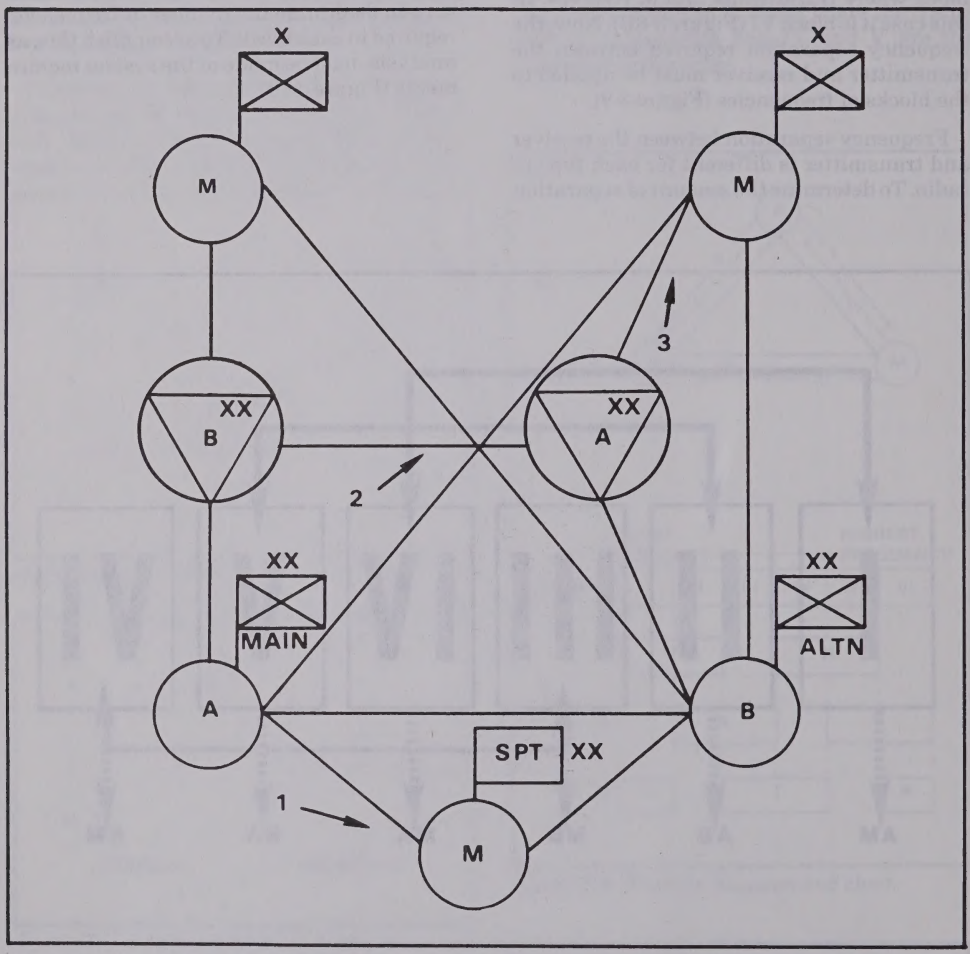


Figure 3-10. Analysis of system requirements.

Table 3-1. Frequency requirements.

A-M	**Block I**	**3 frequencies**
A-B	**Block II**	**4 frequencies**
M-B	**Block III**	**4 frequencies**
M-A	**Block IV**	**3 frequencies**
B-A	**Block V**	**4 frequencies**
B-M	**Block VI**	**4 frequencies**

Divide the allocated frequencies into six blocks (Table 3-2) to include at least as many frequencies for each block as required by your analysis. There is no definite procedure for this division other than trial and error. Separation between respective blocks must be checked, or the method will fail. Separation is determined by the radio set being used. For information concerning frequency separation, refer to the TM for the particular type of radio set being used. Table 3-2 shows examples of frequency division.

Table 3-2. Frequency division.

A-M	A-B	M-B	M-A	B-A	B-M
225	234	262	274	290	347
227	237	268	280	300	356
228	246	270	283	312	358
	250	272		316	360
I	II	III	IV	V	VI
	T			R	
		R			T
R			T		R

At this time, frequencies may be assigned to the system (Figure 3-11). If this entire procedure has been followed exactly, then transmitter-receiver separation is taken care of. However, care must be taken at multichannel relays and terminals to assure that receiver-to-receiver minimum separations are observed.

Double ABM Plan

If the traffic load on a particular route is so great that an additional radio link and additional frequencies are needed, the double ABM plan should be used.

The double ABM plan uses the same six frequency blocks as the single ABM plan. The double ABM plan uses symbols A, B, and M for these blocks and also three more symbols: A^1, B^1, and M^1. Figure 3-12 shows all six symbols in use. Also, this figure shows that a station labeled A can communicate with a station one link away labeled A^1. Four of the six frequency blocks can be used for communication between A and A^1 (two blocks in each direction). Thus, a heavy traffic route could be made up of radio stations labeled A, A^1, A, A^1, etc., similarly B and B^1 or M and M^1 could be used.

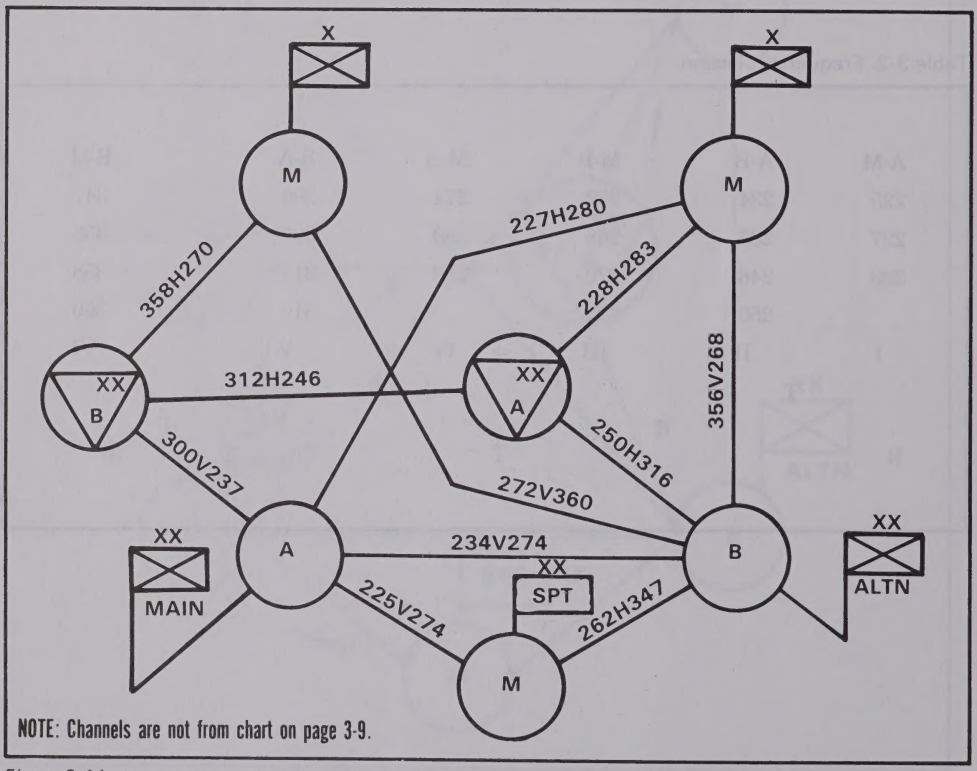


Figure 3-11. Assigned frequencies in a typical multichannel system.

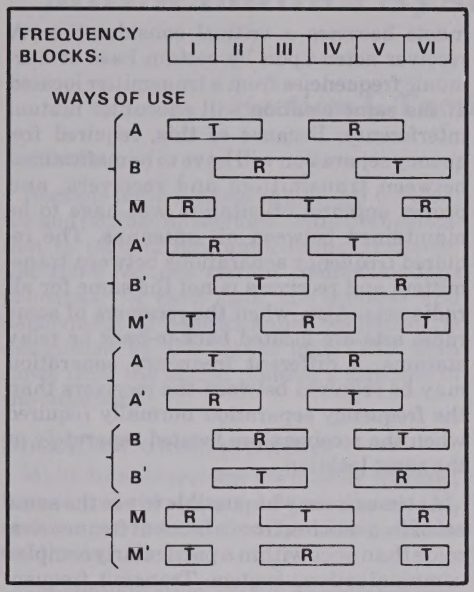


Figure 3-12. Double ABM plan.

Suppose that symbol A is assigned to a station S. Then, on a heavy traffic route, one station, one link away from S could be assigned A^1. On a lighter traffic route, a station one link away from S could be assigned B or M.

The series of symbols with prime and nonprime letters (A, A^1, B, B^1, M, M^1) need not be used for heavy traffic routes only. However, the single ABM series or the single A^1, B^1, M^1 series is better for the lighter traffic routes because it permits a greater number of interconnections.

A route can be made up partly of one series of symbols and partly of another, such as A^1, A, B^1, M^1. Symbol shifts of this kind help in making interconnections.

XY Plan

The XY plan is used when planning a very heavy traffic route. This plan is not as flexible as the ABM and double ABM. For flexibility, it relies on interconnection with them. Interconnection between the XY plan and the ABM or double ABM plan can be worked out by the planning officer.

The XY plan (Figure 3-13) uses the same six frequency blocks as the ABM and double ABM plans. Stations labeled X and Y can communicate with each other (without mutual interference) by using frequencies from four frequency blocks (two in each direction).

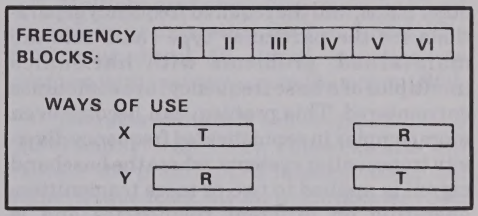


Figure 3-13. XY plan.

If adjacent broad bands of frequencies are divided into six blocks each, it is necessary to avoid transmitter-to-receiver interference between blocks VI and VII (VII is block 1 of the adjacent group). A station using way X in one of the broad bands of frequencies should use way Y in the adjacent broad band and vice versa. This would practically eliminate interconnection possibilities with ABM plans, if both XY and ABM plans were used in both broad bands of frequencies. However, interconnections can be made by placing a guard band between the two broad bands of frequencies and by using way X at the same stations in both bands or by using the XY plan in only one of the two broad bands of frequencies.

Limitations of Frequency Assignment Plans

The frequency assignment plans in this manual have their limitations. Generally, a simple two-block frequency plan will work for any simple isolated system, regardless of the type radio sets used. However, when frequencies are needed for complex systems with more than two transmitters and receivers at the same location, new problems are often encountered.

The ABM plan, double ABM plan, and the XY plan are not the answer to minimizing all the mutual interference problems encountered within all complex systems. When the frequencies used with some radio sets are broken down into blocks according to the ABM and other plans, and the required frequency separations for the particular type radio sets are maintained, problems with harmonics (multiples of a base frequency) are sometimes encountered. This problem can become even more complex in sophisticated frequency diversity troposcatter systems, where the baseband signal is applied to two or more transmitters operating on different frequencies and is received on two or more receivers.

The sensitivity, selectivity, and other technical characteristics of radio sets differ from set to set. When two or more systems utilize the same site, frequency separation between transmit and receive antennas on different masts becomes a critical consideration. A receiver acted upon by certain base or harmonic frequencies from a transmitter located at the same location will encounter mutual interference. Because of this, required frequency separation will have to be maintained between transmitters and receivers, and proper antenna orientation will have to be maintained between all antennas. The required frequency separations between transmitters and receivers is not the same for all radio sets. Also, when the receivers of some radio sets are located back-to-back as relay stations, a different frequency separation may be required between the receivers than the frequency separation normally required when the receivers are located separately at the same location.

At times it may be possible to use the same set of frequencies, from a block of frequencies, more than once within a particularly complex communications system. Transmit frequencies that are the same or close to each other can sometimes be transmitted from the same location, providing that they are transmitted in opposite or near opposite directions. The effectiveness of this method will depend on the selectivity and sensitivity of the receivers used and the overall distances between them.

Generally, the only sure way to minimize the effects of mutual interference between transmitters and receivers is to adhere rigidly to the instructions on frequency management and selection given in applicable TMs. This information will differ for different types of radio sets.

Chapter 4
Multichannel Systems Employment

Section I. Tactical Applications

General

Because multichannel equipment is versatile and flexible, no set rules control its application to tactical communications. However, FM 100-5 requires certain communications priorities. In each case, the amount and deployment of multichannel equipment is designated by the signal plan. This plan flows from the signal planner's estimate of the situation.

Specific Considerations

Multichannel systems are usually operated from terminal to terminal. If relays are used, systems are operated from terminal to terminal through the relays.

The configuration, extent, and composition of multichannel systems are governed by, but not limited to, the following METT-T factors:

- Mission and basic organization for combat.
- Enemy capability.
- Terrain in the area of operations.
- Troops to be assigned for support by higher headquarters.
- Time requirements.
- Location and movement plans of tactical and support units.
- Logistical situation.
- Communications security considerations.
- Electronic warfare environment.
- Availability of multichannel equipment.
- Availability of frequencies.
- Environmental conditions.
- Availability of proper LOS and tropo propagational paths.
- Availability of satellites.

System Procedures

Preoperation.

□ Multichannel operations must be based on a clear and detailed SOP and SOI. The SOP must direct all signal operations to conform with instructions in the current SOI.

□ Extracts of the SOI will be issued to each multichannel team chief. These extracts will contain the prearranged message code, call signs, frequencies, the map coordinates code, the unit authentication system, and data pertaining to the operation of TACSAT ground terminals. The SOI and extracts must be delivered well in advance of need.

□ Each multichannel team chief will be issued tactical maps, coordinates, azimuths, frequencies, codes and unit authentication codes covering the area in which his team will operate.

During operations, any orders for tactical employment must be encrypted. The team chief who receives the message must authenticate the transmission when operating nonsecure. The person originating the instructions must also authenticate.

Some engineering is now done over secure FM radio. Nonsecure transmissions of the following types of information are prohibited:

- Terminal and relay locations.
- Movement instructions to stations.

- Identification of stations with units.
- Instructions regarding future tactical deployment.
- Information on COMSEC devices and material.
- Essential elements of friendly information.

Information regarding changes in a circuit must be transmitted from higher to lower headquarters and vice versa. Such orders will originate from the terminal at the higher headquarters.

Equipment Considerations.

- Radios must operate exactly on assigned frequencies.
- Correct antennas must be used.
- Transmitting and receiving antennas must be oriented properly. When two or more systems utilize the same site, frequency separation between transmit and receive antennas becomes a critical consideration.

System Flexibility

Multichannel systems furnish a wide variety of communications capabilities, including the following:

□ Mobile equipment will be used as jump teams to extend communications in fast moving situations. These teams move to forward, rear, or lateral locations before the actual movement of the headquarters, and establish communications before the old CP is displaced, thus ensuring continuous communications. The jump team monitors communications from the old location and switches the circuits to the new CP when the old station closes.

□ Radio links, multichannel terminals, and multichannel relays may be integrated into a wire system without reducing wire capabilities. Multichannel links can easily span dense forests, swamps, jungles, deep ravines, steep grades, rivers/lakes, or rugged valleys which make wire construction impractical or impossible.

□ Through proper arrangement of terminal equipment, channels may be rerouted without termination over forward or lateral area systems. This procedure is known as strapping through and provides point-to-point circuits over systems normally used for trunk service.

Relays may be arranged to function as multichannel terminal stations. When sufficient terminal equipment is not available, this adaptation may be used. When used in this manner, however, additional multiplexing and ringing equipment is required.

Section II. Typical Use of Multichannel Communications In Division Operations

System Requirements

In all cases, communications needs determine the number and type of systems required to connect units or area signal nodes. After determining system requirements, a terrain analysis with particular emphasis on the terrain between planned terminals will show the number of multichannel sets required for each system. Relief maps and military topographic maps should be used in planning terminal and relay sites. Tropo and TACSAT paths over reasonable distances will eliminate requirements for radio relay sets.

Division Multichannel Communications System

The division communications system is a combination of secure multichannel radio links with occasional cable and terminal facilities installed, operated, and maintained by the division signal battalion. Total commitment of multichannel equipment is seldom made; this allows offensive flexibility. The division signal officer decides the network composition. His decisions are based on the desires of the division commander, the current tactical situation, and available assets.

The division signal battalion companies install parts of the multichannel system as follows:

- Company A, Command Operations Company, provides signal centers at the DCSC and DISSC, and signal support for the division attack CP, DTOC, and DIVARTY.
- Company B, Forward Communications Company, provides a FASC near each FSB, brigade support area (maximum of three), multichannel terminals at each brigade headquarters (maximum of three), and brigade jump to terminate the systems as indicated in the multichannel diagram.
- Company C, Signal Support Operations Company, provides the signal center at DISCOM and division rear area and multichannel radio terminals at the ADA, MI (CEWI), and engineer battalions; the C(AA)B; the FA brigade (corps); and an adjacent division. It provides multichannel radio relays to extend coverage and range of the division multichannel system and installation of PCM cable.

Alternate Multichannel Systems

Some factors such as mission, size of the area of operations, and terrain may require task organizing for a modified multichannel system. The division signal officer has the authority and responsibility to provide that multichannel system which would best serve each situation.

Section III. Multichannel Facilities Displacement

Displacement and Installation

Multichannel systems must be displaced without interruption of communications for command and control. This is done through intelligent, detailed, advanced planning by the commander and the signal officer in close coordination with staff personnel, particularly the G2/G3. Displacement and installation must be rapid in order to maintain pace with the fast moving combat maneuver elements. The signal battalion has to train to fight and communicate. Being positioned across the division area, signal battalion personnel must think beyond front lines and rear area. The time of linear battle or battle lines is dissolved. The natural alignment of communications on high ground and the tactical value of high ground places the signal forces in a vulnerable position. Communications personnel on high ground trained to observe, to call for fire, to identify targets, and to exercise combat skills could provide combat options not usually implemented. As the force deploys, the signal nodes must train harder in site defense, patrol, and battle drills. Enemy air insertions into the division area on high ground are probable. The signal battalion could identify, engage, and return fire until the enemy is destroyed. For safety and operating purposes, power units are emplaced in level positions. There are two methods of displacing a signal node, phased and total.

The phased method of displacement is installing minimum essential communications at the new location. This provides continuity of communications while the CP is displacing. It also enables command and control to be transferred smoothly from the old to the new CP location. The communications are phased out at the old location and built up in the new area. This is done as rapidly as the movement of elements of the headquarters will permit. This process continues until the old location is closed out. The signal officer will always notify signal elements of any expected displacements. This should be done as early as possible for planning purposes. Timely coordination will allow multichannel radio systems to be planned and cable route surveys to be made. Reconnaissance of areas for multichannel terminals, radio parks, and other communications equipment locations should be made before the displacement takes place.

The total method of displacement involves closing out all of the communications at a signal node at the same time and displacing the entire signal node. During this type displacement, the remaining multichannel systems or circuit routing configuration may have to be altered to provide the commander with adequate communications to maintain command and control.

Chapter 5

System Operation Techniques

Section I. Procedure

General

Previous chapters have discussed the different types of multichannel systems, traffic normally handled, and determining the siting of multichannel systems. This chapter will explain the procedures used to align and operate the systems once they have been deployed.

Multichannel System Alignment

The proper alignment of multichannel systems is necessary to ensure the multichannel equipment is adjusted to provide the best possible circuit conditions. Improperly aligned equipment will, at best, provide marginal circuits which are normally unacceptable.

Multichannel Operation

The multichannel operator's job is not finished after the system is properly aligned. The multichannel equipment must be monitored and checked at regular intervals to ensure the condition of the circuits does not deteriorate.

Section II. System Alignment

Overall Multichannel System Alignment

The overall multichannel system must be aligned in accordance with instructions contained in the appropriate equipment TMs. Both the radio system and the multiplexer system are included in the overall system alignment.

Alignment Control

All alignments are supervised by the controlling terminal whose site designator precedes that of the remaining terminals in the MSD. MSDs are found on the multisystem diagram or CRL. Site designators are normally found in the unit SOI.

Intermediate or relay stations report all readings to the controlling terminal during system alignment.

Permission to make alignment adjustments must be obtained from the control terminal. If equipment being used requires critical signal levels to be transmitted over the system, the control terminal must ensure that no more than a 2 db change will result in the system as a result of any one alignment.

Radio System Alignment

The radio system alignment is performed after the starting procedures for each radio set in the system have been made. If connections to the multiplexing system have been made, the control multiplexing terminal must be informed when the radio system lineup is completed. Then the overall system alignment may be accomplished.

The radio alignment procedure is accomplished first in the A-B direction and then second in the B-A direction. When performing the alignment, the controls of the transmitter at radio terminal A are adjusted first. When this has been accomplished, the control radio terminal attendant directs the attendant at the next receiver in the A-B direction to adjust

his receiver to obtain appropriate signal level. When this has been accomplished, radio terminal A then directs that the next transmitter in the A-B direction be adjusted. Each successive receiver and transmitter in the A-B direction is aligned in sequence until the receiver at terminal B is aligned. At this point, radio terminal B assumes temporary control and directs the alignment in the B-A direction.

Overall System Alignment

The overall system alignment is performed for both the multiplexing system and the radio system. The alignment is performed at the direction of the controlling multiplexing terminal. As in the case of the radio system alignment, the multiplexing system alignment is accomplished first in the A-B direction and then in the B-A direction. The procedure followed is the same at both terminal and relay stations (if the relay is a D/I point) as in radio alignment.

System Checks

Monitoring and operating checks must be performed periodically. These checks normally are performed while the system is operating and should not interrupt the normal use of the radio and multiplexing equipment. Equipment manuals provide a list of checks to be performed.

Circuit Tests

Overall circuit tests are required after installation tests have been completed. These tests are made on trunks that are a part of new installations, additions to an existing system, or where trunks have been rerouted by wiring changes or patching. They are made on an overall system basis from switchboard to switchboard (or, if available, from testboard to testboard).

All circuit tests are under the direction of the control facility. The tests include overall signaling and talking, with supervisory checks being made to assure efficient operation. Adjustment and alignment checks are also made to determine if facilities meet performance requirements. Noise measurements are made on all channels and networks. If the overall performance requirements are met, the trunks are released for use. If requirements are not met, they are subjected to section-to-section tests to bring the system up to prescribed standards.

Section III. Multichannel Operation Techniques

Proper Operating Procedures

The tactical effectiveness of any communications equipment is no greater than the skill of the operators. The most efficient communications are attained when the operators use the proper operating procedures. In most cases, the transmitter, output coupling, and antenna feeder circuits must be tuned correctly to obtain maximum power output. In addition, both the receiving and transmitting antennas must be assembled, erected, and oriented properly with regard to both electrical characteristics and conditions of the local terrain. Most receivers are provided with adjustable controls designed to minimize the adverse effects of fading, noise, and interference. Use of the noise limiter and one of the various types of filters often will permit satisfactory reception of signals that would otherwise be lost when noise and interference become excessive. In addition, mux equipment must be properly aligned and connected to the radio equipment. Misalignment of any of the equipment and controls, either through

ignorance or carelessness, may cause unsatisfactory operation. Therefore, the skill, technical proficiency, and operating techniques of the multichannel operator play an important part in the efficiency and reliability of multichannel systems.

Operation Instructions

Instructions pertaining to multichannel systems are contained in the SOP and the SOI. Security procedures to be adopted by operators in the command are included in the SOI. The SOP governs routine operations of a unit. Refer to FM 24-16 for additional information concerning the SOI and the SOP. Also refer to FM 32-6 for detailed information on COMSEC measures.

Hints for Operators

Study and become familiar with the TMs for the specific equipment being used. These outline complete operating instructions and maintenance procedures.

Perform preoperational checks on equipment to ensure its operating reliability before it is installed in any system. Check out the operation of transmitters against one or more receivers, and check out receivers against one or more transmitters. Transmit and receive tuning heads may be interchanged and checked out at the same time. Radio and multiplexing equipment should be placed back-to-back, interconnected, and the transmit and receive sides checked out. When two or more complete radio sets and items of multiplexing equipment are available, they should be connected as a multichannel system for test purposes. Field telephones and monitor teletypewriter sets may then be used to check out the sending, receiving, and ringing circuitry of each channel.

Ensure that power generator sets have a power output rating equal to or larger than the load they are expected to pull. Make sure the battery voltage is correct and the battery charging apparatus is working properly.

Lack of communications or poor communications may be caused by the following:

- Too great a distance between radio sets.
- Poor choice of location (siting) at one or both ends of the system or at some point in between.
- Terrain (hills or mountains).
- Noise and interference.
- Fading.
- Insufficient transmitter power.
- Poor sensitivity or selectivity of receiver.
- Improper adjustment of equipment.
- Defective equipment.
- Improperly oriented antenna or ineffective antenna.
- Improper frequency assignment.
- Cable connectors on cables between components not tight or conductors broken.
- Improperly cabled or wired components.
- Improper switch settings.
- Improper mode of operation.
- Improperly matched equipment (wrong equipment for job).
- Improperly seated or not tightened down pluck-out panels, assemblies, and subassemblies.

Poorly maintained equipment and improper operation can be just as effective in preventing communications as excessive distances or mountainous terrain. It is imperative that the following precautions be observed at all times:

- Keep equipment clean and dry.
- Handle equipment carefully.

- Always consult TMs when in doubt about the operation of equipment.
- Use proper tools (such as, multiplexer alignment tool).
- Always ground equipment before applying power.

Set up routine inspection and maintenance procedures for the following:

- Cleaning plugs and jacks.
- Tightening antenna and power connections.
- Checking knobs and controls for free operation.
- Checking fan motors for smooth operation.
- Cleaning air filters.
- Removing batteries during prolonged storage periods.

General Operation Instructions

Before operating any multichannel equipment, obtain the equipment manual and carefully study the instructions covering the operation. Panel diagrams, connection diagrams, and the paragraph covering the descriptions of components should be referred to during the preliminary starting procedures. This will ensure that the proper cables are connected to the proper panel connectors and the controls are at their proper settings. Even the most experienced operators should check their preliminary procedures against these references. This is to ensure accuracy and to keep abreast of equipment operating changes. Refer to the operational checklist (and, when authorized, the equipment performance checklist) to determine what should be done to remedy unusual occurrences during starting procedures and operation. The checklist provides guidance in the application of corrective measures if the equipment is not performing normally.

Steps Helpful in the Operation of Multichannel Equipment

The multichannel equipment that is issued to units will vary in type according to the communications requirement and mission of the unit. For example, some equipment may be completely contained in one assembly or a few assemblies, while other equipment may consist of many separate components that must be properly connected together. The following information is generally required in operating any multichannel equipment. Consult the pertinent TMs for specific or unique steps not covered.

Check equipment to make sure that all the necessary components and accessories are on hand and ready for use. Also, check to make sure that all fuses are of the proper rating. If properly rated fuses are not on hand, fuses with lower ratings may be used, in some cases, as substitutions. Do not overfuse under any circumstances.

Check knobs, dials, switches, and controls that are loose on their shafts, bind when being operated, are bound so they will not operate, or are damaged in any other way. Make sure that all knobs and exterior parts are on the equipment. Make corrections where possible or report the faulty condition to your immediate supervisor.

Check plugs, receptacles, and connectors. Do not attempt to connect the set for operation until you are sure that the plugs and connectors are clean and in good condition, and that the receptacles to which they must be connected are clean and in good condition.

Check connection diagrams to make sure they show the type and number of cables required to connect the components of the equipment together for each type operation. The equipment may be damaged if cables are connected to the wrong receptacles.

□ If the connectors do not match, it is possible to physically damage the pins or sleeves of the connectors.

□ If a cable is connected to a receptacle which it will fit, but where it does not belong, it is possible to cause serious electrical damage and, in some cases, injury to the operator.

Check dials, switches, and controls for proper settings. Some equipment can be seriously damaged if this is not done before applying power or making the initial tuning adjustments. Before turning on power, check the equipment manual to be sure that all preliminary starting procedures have been covered completely.

Check proper starting procedures covered in the equipment manual. If there is a specific sequence for starting the equipment, it is described in the manual and must be adhered to.

Check power applications referred to in the equipment manuals starting procedures. After the proper connections have been made check to make sure:

- Proper grounds have been established.
- All switches, dials, and controls have been properly set.
- All special conditions and specific requirements for a particular item of equipment have been met.

Then power may be applied to the equipment.

Allow the equipment to warm up. In some cases, it is possible to damage a set by attempting to operate before the tubes are properly warmed up. All equipment that uses electron tubes requires a warm-up period to permit the tubes to reach their efficient operating condition. Most equipment is protected against such damage, but it is not a good practice to risk damage to the equipment by trying to operate it before it is warmed up. On very cold days, teletypes should be allowed to warm up by allowing the shelter to warm up.

Watch all indicators, meters, and dial lamps for abnormal operation during warm up. From the time the power is turned on until the equipment is warmed up and ready to operate, observe if any of these indicate an unusual condition, investigate immediately. Circuit breakers are provided on most equipment to protect against burnouts caused by overloads, but other malfunctions may occur that will not trip the circuit breaker. These other malfunctions may also damage the equipment.

Tune radio equipment to the desired frequency. Tune the transmitter to its proper frequency (the frequency of the desired channel) according to the procedures described in the equipment manual. Tune the receiver to its proper frequency. Use the methods that are given in the equipment manual to check for correct tuning. Always turn off equipment before tuning to a new frequency. Failure to do so may result in a damaged tuning head.

Check equipment and indicators frequently, while in operation, to ensure that the equipment is operating correctly. If any unusual operation occurs, investigate it immediately. If necessary, turn off the power to the equipment and refer to the operational checklist and the equipment performance checklist. If the corrections given in these checklists or the equipment's troubleshooting instructions will not correct the trouble, report the equipment's condition to higher echelon maintenance. Make sure that the condition of the equipment and the action taken are properly recorded on the maintenance records.

Use proper turnoff procedures. After operation has been completed, or if the equipment is being turned off because of improper operation, ensure that the controls, switches, and dials are properly positioned (this may not be required on some equipment). Shut down the components of the equipment in the sequence

specified in the equipment manual. Simple communication equipment may require nothing more than turning the power switch to its off position, but more complex equipment may require elaborate shutdown procedures.

Operator Procedures

Technical proficiency is not enough to ensure efficient and reliable multichannel systems. Effective communication is the result of a combination of things so closely related they often overlap. Technical proficiency coupled with good operating techniques, COMSEC and ECCM combine to make effective multichannel systems. Some procedures that all multichannel operators should be familiar with, and proficient in, are as follows:

- Time conversion.
- Use of phonetic alphabet.
- How to authenticate.
- When to authenticate.
- Map reading (FM 21-26).
- Transmission security measures (FM 32-6).
- Access to and dissemination of restricted data (AR 380-150).

SOP for Operators

All terminals, relay stations, and other manned facilities in a multichannel system should establish SOPs for the operation and maintenance of equipment, the physical and cryptographic security of COMSEC equipment and material, and for the maintenance of station records. These operating procedures are established to meet the requirement of the unit or organization served by the communications facility.

Operator Duties

The multichannel operator must always use the prescribed operating procedures. Unauthorized changes in procedures invariably create confusion, reduce reliability and speed, and decrease COMSEC.

Before an operator turns his equipment over to the operator who relieves him, he should pass on to his relief special orders and information concerning his equipment or facility. This should include all necessary or useful information concerning system and circuit changes, and frequency changes. It should also include performance of the equipment during the previous period of operation, status of backup equipment, and other pertinent data. This information should be contained in the master station log.

Before taking over the equipment or facility, the relieving operator should check the equipment to ensure that it is in efficient operating condition, properly aligned, and tuned to the assigned frequency.

Multichannel operators will improve communications if they observe the following general rules:

□ Develop a system of rings to reach each attended point in the system.

□ Use the orderwire circuit for engineering and coordination purposes only.

□ Maintain an alert watch on all systems and circuits to ensure that transmitter and receiver frequencies are within tolerance and that operating channel levels are within the specifications of equipment design.

□ Use only prescribed operating procedures, and conform with the regulations for maintaining transmission security. Remember, the orderwire is not secure!

Section IV. Control of Multichannel Systems and Circuits

Signal Operation Instructions

SOI must be established and distributed throughout the communications system to ensure efficient use of signal personnel, equipment, and facilities (means).

Control of Communications

Systems and technical control facilities must be established to assist commanders in controlling communications systems.

□ CSCE (formerly SYSCON) commands, controls, and manages signal facilities and is normally established at battalion level and higher. CSCE functions include detailed signal system planning and engineering, including traffic analysis and engineering. The CSCE coordinates, directs, and controls the implementation, integration, and operation of a communications facility and establishes communications priorities.

□ CNCE (formerly TECHCON) technically manages and/or controls signal communications to include establishing routing, rerouting, patching, and discontinuing circuits/systems. CNCEs are normally located at command and area communications nodes.

The control facility must maintain current status on all communication systems and circuits within its responsibility and pass this information to the control facility at the next higher echelon.

Use of Orderwires

Orderwire circuits are used for system and circuit alignment. The orderwire is used by the radio operator to work his system in. It is nonsecure. Channel 12 is usually designated as the engineering circuit.

Use of Intercommunications Stations

Intercommunication stations are used for voice communications between communications assemblages and facilities within a particular site or location. Intercommunication stations are preinstalled in mobile communications shelters. Other units may be installed in additional facilities. Intercommunication stations are used for service purposes and provide two-way, nonprivate communications in a system with like equipment. Where intercommunication stations are not available, field telephones may be used. If secure equipment is used, use TEMPEST HAZARD precautions.

Section V. Noise, Interference, and Fading

Noise, Interference, and Fading at Receiver Locations

The amount of noise, interference, or fading at the receiver location limits the distance between multichannel links. The more noise, interference, or fading that is present, the shorter the distance that can be covered. A high noise level will reduce quality in telephone circuits and cause errors in teletypewriter messages. In the automatic switching system, an excessive noise level can cause trunk call blockage.

Noise in Multichannel Systems

The two basic types of noise existing within multichannel systems are idle noise and intermodulation noise.

Idle noise is always present in a system, with or without modulation. Idle noise includes thermal noise generated within the equipment by mixer diodes, low level amplifiers, and shot noise from klystrons.

Intermodulation noise is introduced into the system as a result of signals being transmitted on other channels. The greater the traffic load, the more intermodulation noise introduced. Usually intermodulation noise increases slowly until a break point is reached, after which, it increases rapidly. Generally, it is desirable to operate the systems at as high

a signal level as possible (short of the break point) in order to improve the S/N ratio. For most equipment, however, specific signal levels must be maintained to ensure proper operation.

Operation with High System Noise

Occasionally traffic channel noise is excessive. This may be caused by a higher noise level at one or more radio links than at others. A link may have a relatively high path attenuation due to a long transmission path or LOS obstructions. A high noise level may also be caused by external sources such as ignition or radio interference.

It may be possible under such conditions to improve the system's S/N ratio by increasing the signal output of the transmitter and reducing the gain of the receiver where the high noise level occurs.

Follow the corrective procedures outlined in the equipment manual when a particular link is operating with excessive noise.

Interference in Multichannel Systems

Most interference in multichannel systems is generally of three types: interference from natural sources, man-made interference, and mutual interference. The prime requirement for good communications is a high S/N ratio.

Radio interference from natural sources may be divided into four classifications:

- Atmospheric interference: electrical storms.
- Solar and cosmic interference: eruptions on the sun and other stars.
- Precipitation static from charged particles in the atmosphere. Particles may be rain, sleet, snow, sand, smoke, or dust. Dry particles produce greater charges than wet ones.
- Fading from disturbances in the medium through which radio waves are propagated.

The interferences listed above appear in electronic equipment as audible noise or errors in the output of some terminal equipment. There is some interference at most frequencies, but the higher the frequency the less noise.

Man-made interference is generated by electrical devices, such as vehicle ignition systems, motors, generators, and other rotating machines. Unshielded electrical equipment, power lines, certain hospital equipment, and power units are sources of man-made noise. If this interference is not controlled, reception will be poor. Man-made interference is best eliminated or minimized at its source, and some improvements can be made at the receiver. Normally, all receiving equipment is located away from heavy motor traffic routes, and vehicles are not permitted within 180 meters (200 yards) of receiver antennas. Some of the interference will be eliminated by the directional antennas provided for use with the radio sets used in multichannel systems.

Mutual interference is when one communications system interferes with another or when one unit in a system interferes with other units in the same system. Mutual interference may appear in several forms, such as noise, cross talk, and harmonic interactions. Some of the common conditions that cause mutual interference are as follows:

- Transmitter fundamental radiation to receiver fundamental response.
- Transmitter spurious radiation to receiver fundamental response.
- Transmitter fundamental radiation to receiver spurious response.
- Transmitter spurious radiation to receiver spurious response.
- Receiver radiation to receiver fundamental response.

- RF arcing in transmitters.
- Impedance mismatch in the antenna system.
- High-voltage pulse interference.
- Improper frequency assignments.
- Nuclear detonation causes radiation and debris.

□ Spurious radiation refers to signals radiated from the transmitter on many frequencies other than the fundamental or carrier frequency. While these spurious radiations are weaker than the fundamental or carrier frequency, they may be strong enough to cause interference noise in nearby receivers. This is true especially when a receiver is tuned to a frequency corresponding to one of the spurious transmitter radiations.

□ Interference signals may be amplified to the point where they will render the desired signal unintelligible if they are strong enough. It is possible for the local oscillator in a superheterodyne-type receiver to radiate a signal which can cause interference. This is known as receiver radiation.

□ Mutual interference may originate from many local and distant sources. Frequency relationships, geographical locations, faulty adjustment of equipment, improper operating techniques, and weather conditions are factors contributing to mutual interference. Equipment and systems that are potential generators of mutual interference include radar, radio, and radio aids to navigation.

Fading

Fading may generally be considered a form of interference. It is not normally caused by man-made interference or sources outside the transmission medium. Fading is the variation of radio field strength caused by changes in the transmission medium with time.

All frequencies used in multichannel links are subject to fading. The use of automatic gain control in the receiver will compensate for minor changes in signal intensity. Though fading can occur along any transmission path, the effects of fading are not as pronounced on VHF, UHF, and TACSAT paths as it is on microwave and tropo paths. Other aspects of fading, and measures to combat them, are discussed in the following paragraphs.

Microwave Fading Aspects

For paths above the horizon, two general kinds of microwave fading exist: inverse-bending and multipath. They differ in origin, character, locations where they are most prevalent, and effects on communication.

□ Inverse-bending fading is typically found over water. It is rare over land, except on some foggy paths near large bodies of water. The individual fades may last for minutes or hours until the climatic phenomena no longer exists.

□ Multipath fading may occur over many kinds of paths. It may result from reflections from water or highly reflective earth. At the longer distances, it may be a result of refraction from an elevated layer of troposphere. It may also result from adjacent multiple paths caused by local irregularities in the troposphere. The duration of individual multipath fades is from about a second to a minute.

Both kinds of fading may occur at the same time on the same path. When the signal is weakened by inverse-bending, it is more subject to multipath effects.

The maximum depth of fading occurs when the air is still and humid and the ground is warmer than the air. The minimum depth of fading occurs when the air is dry and well stirred by winds. Therefore, deep fading is ordinarily seasonal.

The depth of fading tends to be greater at longer distances, but climatic conditions are fully as important as distance. The amount of fading, or its time of occurrence, cannot be accurately predicted and therefore must be estimated.

Fading results in a poorer S/N ratio. When the audio S/N ratio is seriously impaired by fading, telephone communication becomes difficult, errors appear in the telephone signaling and in VF teletypewriter traffic, and facsimile reproductions show spots, blotches, or blackout. If the fade is deep enough, the signal is entirely lost in the noise.

In PCM systems, when the RF signal weakens, the audio S/N ratio is about proportional to the RF S/N ratio until the latter reaches a low value called the breaking point. If the RF signals are weaker than this breaking point, the audio noise increases much faster than the RF signal decreases. The margin between the steady-state conditions and the breaking point is sometimes called the fade margin. When the breaking point is reached on any system, the noise has already reached a level above the 0-db transmission level. This seriously impairs reception.

One Percent Microwave Fading

One percent fading is taken as the depth of fade (in db) that is exceeded only 1 percent of the total time in the worst month of the year in the locality concerned. This is approximately 7 hours assuming 24 hours a day operation. One percent fading is the sum of all the separate intervals that the depth of fade exceeds the stated amount. General fading conditions may extend over a period of several hours (usually in the early morning hours during worst month conditions). However, the deep fades that exceed the stated amount for 1 percent fading criteria are of very short duration, ranging from a few seconds to a minute or so. Thus, out of the total period that disturbing fades exist, only a total of a few minutes would exceed the stated amount for 1 percent fading criteria.

Microwave fading estimates are based on an expected 1 percent fading depth of 20 db on a single 56-kilometer (35-mile) link. In the month of worst microwave fading, the db depth of fade, with good siting, will vary above or below 30 db based on the square root of the link length. When one link has a deep fade, the others will seldom have one at the same moment. These figures apply when there is good path clearance. At, or just above, grazing (on the basis of K = 4/3 true earth radius), the fading probably would be about 6 db deeper.

General Measures to Combat Microwave Fading

Avoid paths where deep fading is likely.

Make the path loss low enough to provide adequate fade margin.

Use space diversity when needed.

Raise the antenna higher than just enough to give free space loss when fading is of the inverse-bending type (slow fading). Clearance (above the grazing line over the surface of the earth or the most prominent obstacle) approximately twice the height necessary for free space loss is recommended in this case. If fast fading also is prevalent, use space diversity.

Space Diversity

To use space diversity (Figure 5-1), a second receiving antenna is so placed that when the signal at the first receiving antenna is weak, the signal at the diversity antenna is relatively strong. To do this, the two antennas must be properly spaced. Each antenna must connect to its own receiver, and the receiver outputs must be connected through a combining circuit actuated by control voltages taken from the two receivers.

When fading is of the inverse-bending type, space diversity ordinarily is not helpful, unless the second antenna can be placed considerably above the original antenna.

Fading effects are not completely eliminated by the use of space diversity, but the duration of a poor S/N ratio is considerably reduced.

The space diversity antenna usually is placed from 15 to 30 meters (50 to 100 feet) directly below or above the first receiving antenna (Figure 5-2). Only a rough practical rule can be used, so considerable changes in antenna spacing may be necessary. Spacing of even less than 15 meters (50 feet) may be effective. Frequency diversity may also be used to minimize fading on microwave systems.

Aspects of Tropo Fading

In a long-range tropo communications system, the signal energy arrives at the receiver over a number of paths. The signals from the various paths may have different attenuation, phase, and polarization. This multipath effect leads to variations in the net received signal strength as follows:

□ Fast fading may take place in fractions of a second. It results from signals arriving randomly at the receiving antenna.

□ Slow fading occurs over time intervals of several minutes to several hours. Signal variations on the order of 15 db are to be expected.

□ Nuclear detonation causes radiation and debris.

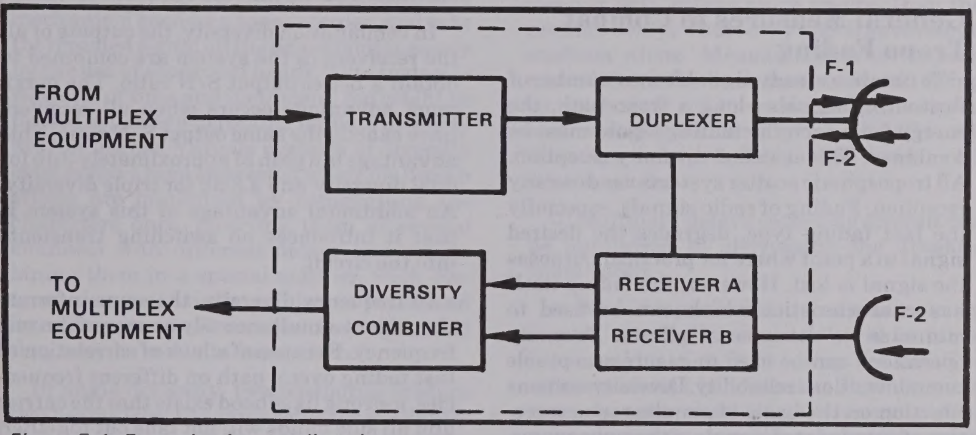


Figure 5-1. Example of space diversity.

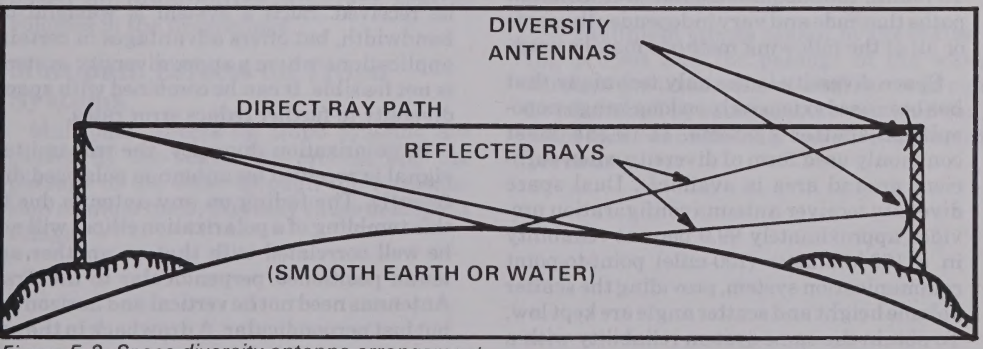


Figure 5-2. Space diversity antenna arrangement.

Long-term fading results from gradual changes in the atmosphere and cannot be reduced. However, short-term fading is determined by the instantaneous arrangement of turbulence in the scatter volume. This instantaneous arrangement appears differently at two separated receiving points. The short-term fading characteristics of the two signals are different. When one signal is at minimum, it is possible that the other signal will be at maximum. If a receive system is used that continuously selects the stronger of the received signals, the circuit reliability will be increased.

General Measures to Combat Tropo Fading

To obtain a steady signal from a number of fluctuating signals along a tropo path, the energy from each fluctuating signal must be combined. This is called diversity reception. All tropospheric scatter systems use diversity reception. Fading of radio signals, especially the fast fading type, degrades the desired signal to a point where for practical purposes the signal is lost. However, the fading itself has characteristics which can be used to minimize its detrimental effects. Diversity operations can be used to ensure acceptable communications reliability. Diversity systems function on the basis of simultaneous reception of uncorrelated signals of the same source. To obtain an adequate signal over different paths that fade and vary independently, some or all of the following methods may be used:

Space diversity is the only technique that has been used extensively on long-range tropospheric scatter systems. It is the most commonly used form of diversity when sufficient ground area is available. Dual space diversity receiver-antenna configuration provides approximately 99.9 percent reliability in a 160-kilometer (100-mile) point-to-point communication system, providing the scatter volume height and scatter angle are kept low. To obtain the same system reliability with a single receiver-antenna system would require either an increase in transmitter power, a decrease in receiver noise figures, or an increase in overall antenna gain. In a space diversity system, the outputs of the individual receivers are switched or combined in such a manner as to ensure the best possible S/N ratio in the final diversity signal.

In switching diversity, the signals from each receiver are compared and only the best signal is selected and all other signals are totally rejected. The switching is done electronically and introduces some transients (variable effects) into the system.

In combination diversity, the outputs of all the receivers in the system are combined to obtain a better output S/N ratio. The maximum advantage occurs when all receivers have exactly the same output S/N ratio. This advantage is a gain of approximately 3 db for dual diversity and 4.8 db for triple diversity. An additional advantage of this system is that it introduces no switching transients into the circuit.

In frequency diversity, the same information is sent simultaneously on more than one frequency. Because of a lack of correlation of fast fading over a path on different frequencies, a strong likelihood exists that the carrier and all side bands will not fade out together, and at least one frequency will nearly always be received. Such a system is wasteful of bandwidth, but offers advantages in certain applications where a space diversity system is not feasible. It can be combined with space diversity to further reduce error rates.

In polarization diversity, the transmitted signal is received by antennas polarized differently. The fading on any antenna due to this tumbling of a polarization ellipse will not be well correlated with that on another antenna positioned perpendicular to the first. Antennas need not be vertical and horizontal, but just perpendicular. A drawback in the use

of polarization diversity is the lack of a good directive antenna suitable for any usable polarization configuration. Pairs of various perpendicular shapes have been used with some success. When the diversity is due to differences in polarization, sometimes the delay time of the strongest arriving signal will shift back and forth when a different mode predominates at a given instant. The strongest signal may arrive milliseconds earlier in one polarization than the other. The effect might cause jitter problems in TDM.

Since in time diversity signals fade, it is possible to repeat the characters, record on a mechanism such as a tape recorder, and take the repeated signal off the tape simultaneously by the use of separated heads. This system is wasteful of time and inefficient, but might be needed in places where other forms of diversity are not usable. Various systems of diversity exist or have been suggested where multipath effects are minimized by transmitting the characters once, receiving them in several channels with different delays and recombining them in a special manner. Such systems can potentially minimize interband interference as well as selective fading, but they may be costly in bandwidth.

In angle diversity, two feedhorns produce two beams from the same reflector at slightly different angles. This results in two paths based on illuminating different scatter volumes in the troposphere.

Multipath Effects on Tropo Systems

Multipath effects on tropo systems are caused by the scattering process and the passage of the wave through the transmission medium itself; this may cause multipath delays.

Aircraft flying through the beam of a tropo path will reflect wave components from the body of the aircraft. These reflective components, being mirror-like reflections, will have either additive or subtractive effects on the portions of the transmitted signal that are passing around the aircraft and thus cause fading in the received signal. These reflected components may also shoot out to either side of the aircraft, strike the scattering area on either side, and scatter signals back to the receiving antenna over a different and longer path than the normal transmission path. These extraneous signals will arrive at the receiver with delays much greater than the normal delays caused by the transmission medium alone. Measurements on experimental circuits indicate that an aircraft flying as much as 3° off the main path of a signal with a beam width of 6° at 40 MHz will introduce multipath delays of as much as 1.5 microseconds.

- Multipath delays caused by aircraft can be minimized by decreasing the antenna beam width.

- When tropo circuits terminate near an airport, the flight patterns should be taken into consideration in choosing the site. The antenna should be located so that the main beam does not pass through or near any of the normal runway approach or takeoff lanes, or the bad-weather holding areas.

- Multipath effects caused by the scattering process and the passage of the wave through the transmission medium itself can be minimized by using one, or a combination, of the methods of diversity reception explained previously.

Section VI. Multichannel Communications Diagrams and Records

Maintenance of Diagrams and Records

In order to become more proficient, the operator should familiarize himself with the diagrams and records necessary to properly maintain and operate tactical multichannel communications systems. The individual operator may or may not come in contact with all the records and reports required for tactical multichannel communications systems. However, he should try to gain a working knowledge of as many as possible. This will require a knowledge of some military symbols. Particularly, a knowledge of the symbols used for military organizations, installations, and communications diagrams will be an asset.

Division Multichannel Diagram

A division multichannel diagram (Figure 5-3) shows a multichannel system that supports a major command. The diagram indicates locations of multichannel radio terminals and intermediate relay stations by map coordinates, location of signal centers and subordinate elements being served by the multichannel radio terminal sites, operating frequencies and antenna polarization, site elevations, system designators, and the security classification.

This diagram ensures effective, accurate control and operation of an area communication system. Multichannel system diagrams are prepared by the signal sections of major commands and senior signal units for planning purposes. Normally, they are issued as an appendix to the signal annex to the command OPORD.

Corps Multichannel Diagram

A corps multichannel diagram (Figure 5-4) is an illustration in symbol form. It shows the number of multichannel systems in operation between signal nodes in a communications network.

Circuit Switchboard Diagram

Figure 5-5 is an illustration in symbol form showing the number of common-user telephone trunks between switching centers of a communications network. It also shows access points to the signal centers or switching centers of higher, lower, and adjacent commands.

A circuit switchboard diagram provides a simplified, easily interpreted reference for determining trunk routing within a communications network, and aids the switchboard operator in routing local and long distance calls.

Circuit switchboard diagrams are published in signal OPORDs or in a technical directive issued by a CSCE. Also, simplified circuit switchboard diagrams are sometimes published as a part of the telephone directory to assist subscribers in selecting call routes.

Line Route Maps

Line route maps (Figure 5-6) provide a graphic means of specifying and recording wire and cable routes in a communications system. They are keyed to topographic maps or map substitutes and generally are prepared as overlays.

The line route map's purpose is to show graphically the actual or proposed routes of wire and/or cable lines, as well as the location of facilities associated with the lines.

Line route maps are provided initially by personnel of each major command signal section. Line route maps are issued as a part of a plan or operations order or as a part of a technical service order to the supporting wire and cable construction units for implementation.

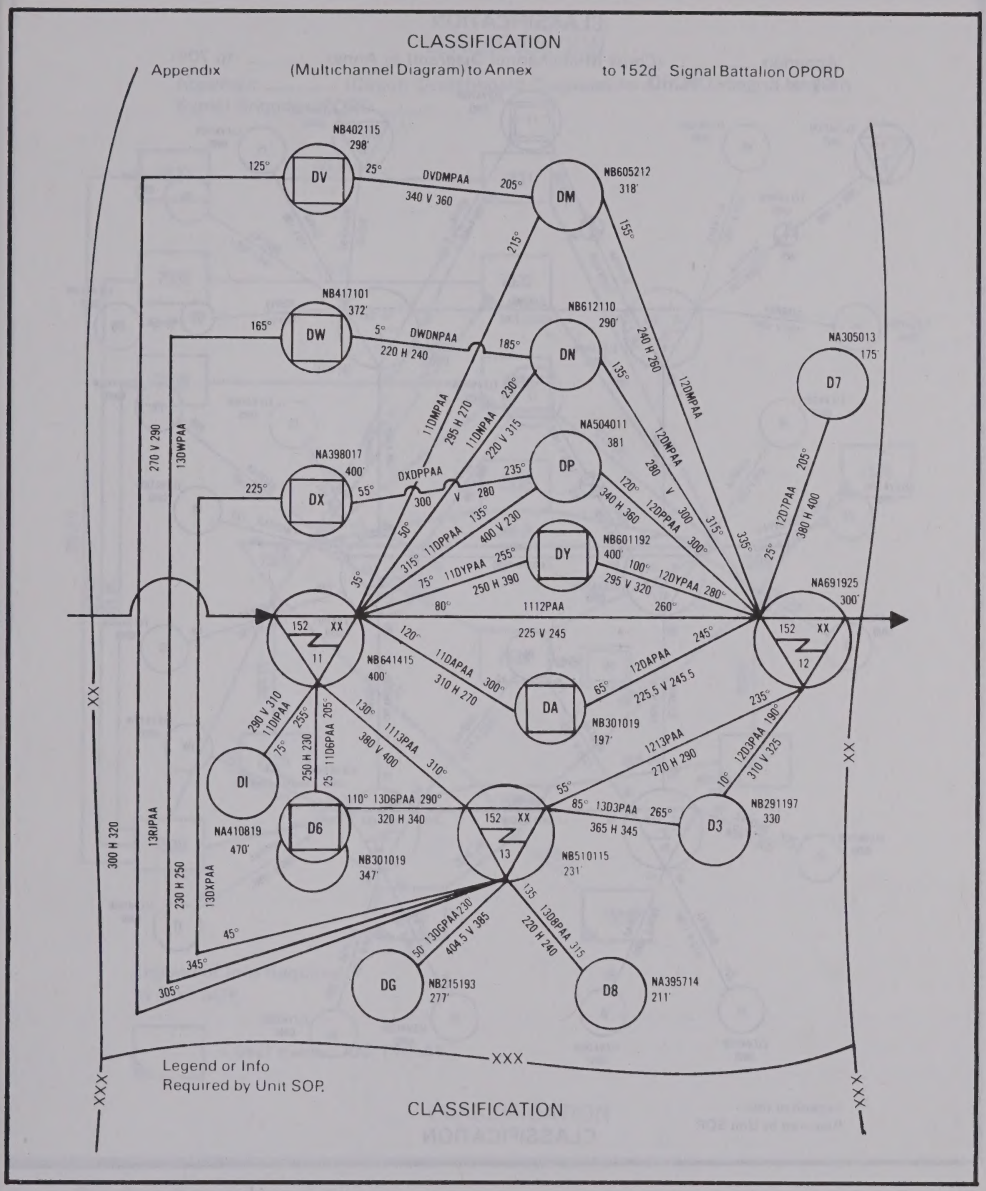


Figure 5-3. Division multichannel diagram.

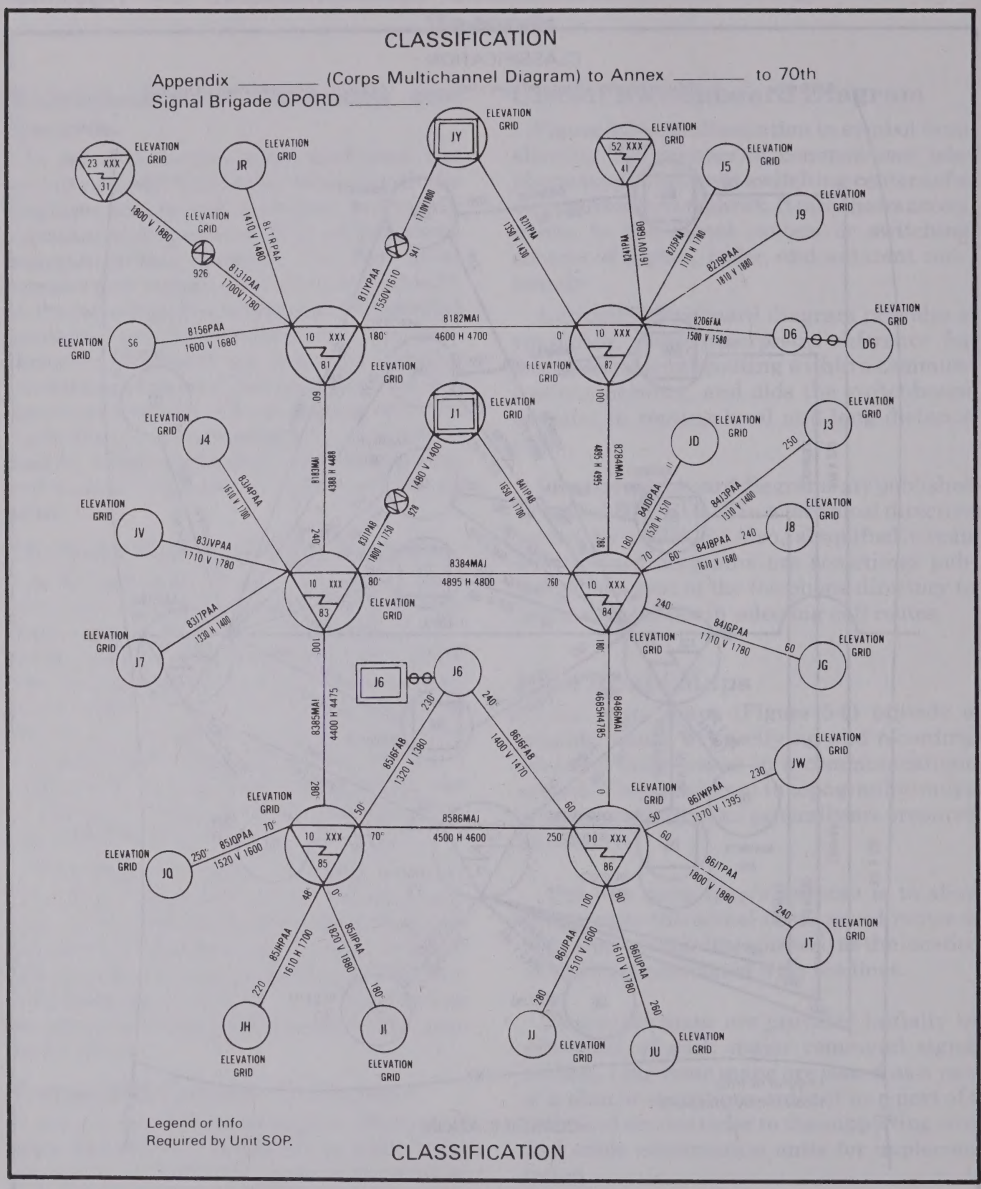


Figure 5-4. Corps multichannel diagram.

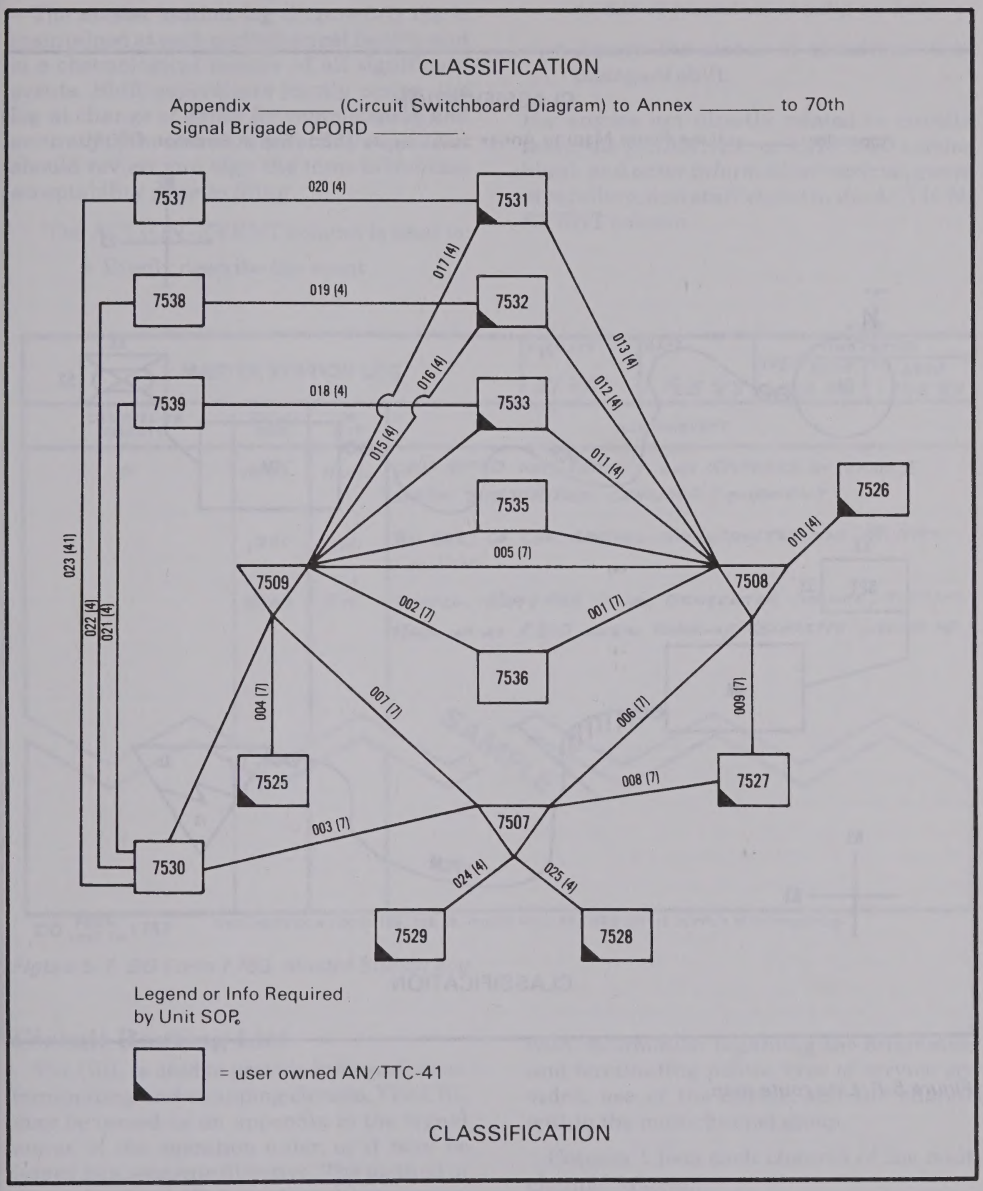


Figure 5-5. Circuit switchboard diagram.

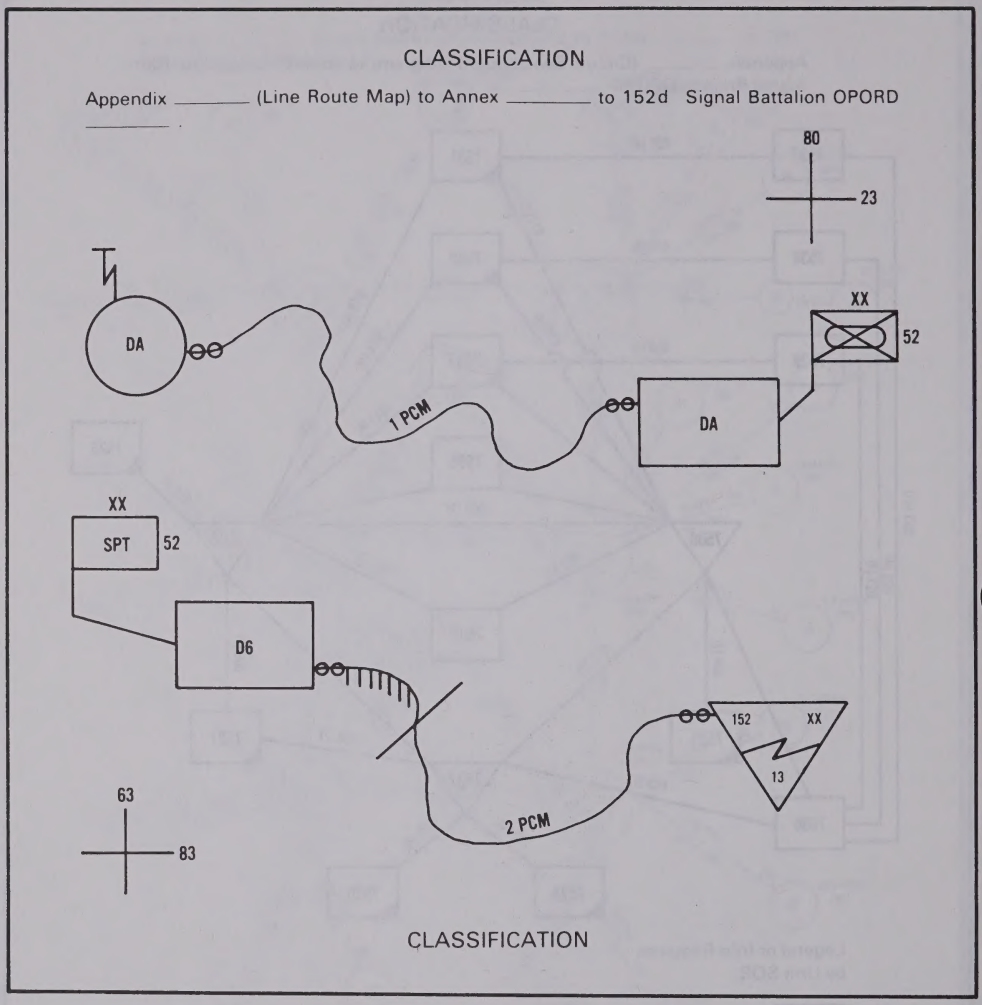


Figure 5-6. Line route map.

Master Station Log

The master station log (Figure 5-7) file is maintained at each multichannel facility and is a chronological history of all significant events. Shift supervisors jointly review the log at change of shifts for completeness and accuracy of the entries. The facility supervisor should review and sign the form to indicate acceptability prior to filing.

The ACTION/EVENT column is used to:

- Briefly describe the event.
- Record shift changes including the names of personnel coming on duty.
- Record the status of circuits at the change of shift.

For entries not directly related to circuits, leave the CHANNEL or CIRCUIT column blank and enter information (such as, generator failure, and staff visits) in the ACTION/EVENT column.

PAGE

MASTER STATION LOG	FACILITY	DATE	TIME PERIOD FROM	TIME PERIOD TO
	8146	1 FEB 88	1200 1 FEB 88	2400 1 FEB 88

CHANNEL OR CIRCUIT	ZULU TIME	OP INIT	ACTION/EVENT
10	1635	H.M.	CH10 RPTD OUT, CIRCUIT WAS RESTORED AT 1700 Z WHEN SUBSCRIBER CHANGED EQUIPMENT
	1800	P.M.	BN CDR, CO CDR ARRIVED AND INSPECTED THE McHAN FACILITY
	2300	P.N.	SYSTEM RA98PAA DOWN, GENERATOR FAILURE, SYSTEM BACK UP AT 2310 WHEN BACK-UP GENERATOR WARMED UP

SAMPLE

DD FORM 1 SEP 70 1753 REPLACES DCA FORM 193, JUL 68, WHICH WILL BE USED UNTIL SUPPLY IS EXHAUSTED

Figure 5-7. DD Form 1753, Master Station Log.

Circuit Routing List

The CRL is used to provide information on terminating and strapping circuits. The CRL may be issued as an appendix to the signal annex of the operation order, or it may be issued as a separate directive. The method of dissemination will depend on the preparing CSPE. The content of the CRL (Figure 5-8) provides the CNCE/multichannel operator with information regarding the originating and terminating points, type of service provided, use of the circuit, and the channel within the multichannel group.

Column 1 lists each channel of the multichannel system.

Column 2 contains the circuit designator based on information contained in FM 24-22.

Column 3 gives the priority designator of the circuit.

Column 4 indicates the type of circuit.

Column 5 indicates where the circuit originated.

Columns 6 through 9 list the systems through which the circuit is patched. The first entry (column 6) is where the circuit originated, and the last entry will be where the circuit terminates. The system designator configuration is explained in FM 24-22.

Column 10 indicates the channel and ringer settings. The settings to the left of the slash (/) mark are the switch settings for the controlling terminal A. The settings to the right of the slash(/) mark are for the distant terminal B. For example, Channel 4 in Figure 5-8 will be set as follows:

□ A terminal sets the channel and ringer switch to the 4W position and turns the ringer to the OFF position.

□ B terminal sets the channel and ringer switches to the 2W position and turns the ringer to the OFF position.

Column 11 indicates where the circuit terminates.

Item 12 is the priority of the system (RIF6PAA). The system priority is the same as the highest circuit priority carried on the system, excluding the engineering circuit between CNCEs.

The information contained in the CRL may not always be in this particular format, but it is essential information which the CNCE/multichannel operator must have in order to properly install and troubleshoot the individual circuits.

	1 CIRCUIT	2 PR	3 TY	4 FROM	5 SYS 1	6 SYS 2	7 SYS 3	8 SYS 4	9 CHANNEL SETTING	10 TO
1	421J161	3C	CU	9221	21J1PAA—01				4W OFF/4W OFF	8765
2	10123ZZ	3C	SU	EW	0121PAC-02	21J1PAA 02	23J1CAA-01		4W OFF/4W OFF	EW
3	622J133	4B	SU	S3	2122PAC-01	21J1PAA-03			4W OFF 2W OFF	G3
4	G01J14C	3C	TT	TCC	0121PAA-01	21J1PAA-04			4W OFF/2W ON	MR
5	322J121	4A	CU	9222	2122PAC-02	21J1PAA-05			4W OFF 4W OFF	8765
6	B22J18E	3A	SC	DATA	2122PAC-06	21J1PAA-06			4W OFF 4W OFF	TADS
7	421J162	3C	CU	9221	21J1PAA-07				4W OFF 4W OFF	8765
8	G21J11C	3B	TT	MR	21J1PAA-08				4W OFF 4W OFF	MR
9	82123GG	4A	LL	9221	21J1PAA-09	23J1CAA 02			4W OFF 4W OFF	SASP
10	102J1HH	3C	SU	CBRE	0102PAA-01	0122MAA-01	2122PAC-08	21J1PAA 10	4W OFF 2W ON	CBRE
11	121J1CC	1A	SU	CNCE	21J1PA-12				2W ON 2W ON	CNCE

Figure 5-8. Content of the CRL.

SYSTEM 21J1PAA
PRIORITY 3A
PAGE 14

Chapter 6

Multichannel Operations Under Adverse Environmental Conditions

Section I. Abnormal Operation, Techniques, and Requirements

General

Unusual terrain, nuclear and chemical environments, and extreme climatic conditions have a significant effect upon multichannel systems. These conditions may require the use of other than normal operating techniques.

Personnel and Equipment

Personnel require special training to be able to operate in unusual terrain, nuclear and chemical environments, and extreme climatic conditions. In addition, they must be given survival training for these conditions.

Communications equipment that is to be operated under these conditions may require modifications and frequent maintenance. These modifications and maintenance requirements are covered in the equipment manual.

Section II. Operation in Arctic Areas

Advantages and Limitations

Multichannel systems have certain advantages and limitations that must be carefully considered when operating in arctic regions. In spite of its limitations, radio is the normal means of communications in the arctic. Operation of communications equipment in arctic areas presents many difficulties. However, most of these difficulties can be overcome through training of personnel and proper selection of equipment and frequencies. Refer to FM 31-71 for additional information on arctic operations.

One of the most important advantages of multichannel equipment in polar regions is its mobility. Most tactical communications equipment is vehicle-mounted and air transportable.

Ionospheric disturbances, in the form of magnetic storms, have a limiting effect on LOS, TACSAT, and tropo radio links, and on sky wave propagation.

Equipment Installation in Arctic Areas

It is difficult to establish good electrical grounds in the arctic because of permafrost. The frozen ground makes installation of ground stakes or ground plates quite difficult and the conductivity of frozen ground is often too low to provide a good electrical connection. Therefore, a partial ground or some type of above-the-ground grounding system should be used in arctic areas.

□ Use existing grounds, such as metal structures or underground pipes, whenever possible.

□ Drive several ground stakes to the greatest depth possible, at various locations. Connect ground cable to each stake and tie each cable to a central point which will serve as ground. Even though each stake may not represent an effective ground, together, they represent a more effective ground.

□ In some cases where a partial ground can be established and the conductivity of the soil is low, chemicals can be used to increase the conductivity (Figure 6-1). Some chemicals that can be used are calcium chloride, copper sulphate (blue vitriol), magnesium sulphate (Epsom salt), and potassium nitrate (saltpeter). The amount required depends on the type of soil and its moisture content.

The major problem with antenna equipment for arctic operations is installation. Installation time will be increased due to adverse working conditions.

□ The mast sections and antenna cables will become brittle and must be handled with care.

□ Antenna cables should be constructed overhead, whenever possible, to prevent damage from heavy snowfall and frost. Radius ropes should not be left out in arctic weather. Nylon rope, if available, should be used instead of cotton or hemp, because nylon does not readily absorb moisture and is less likely to freeze and break.

□ Antennas must be strong enough to withstand high wind and ice loading as well as extreme temperature changes. Heavy ice coating may deform the shape of antennas enough to distort the antenna lobing pattern. This can be especially true with parabolic reflectors. Safeguarding against excessive ice coating of dipoles or other feeder devices is

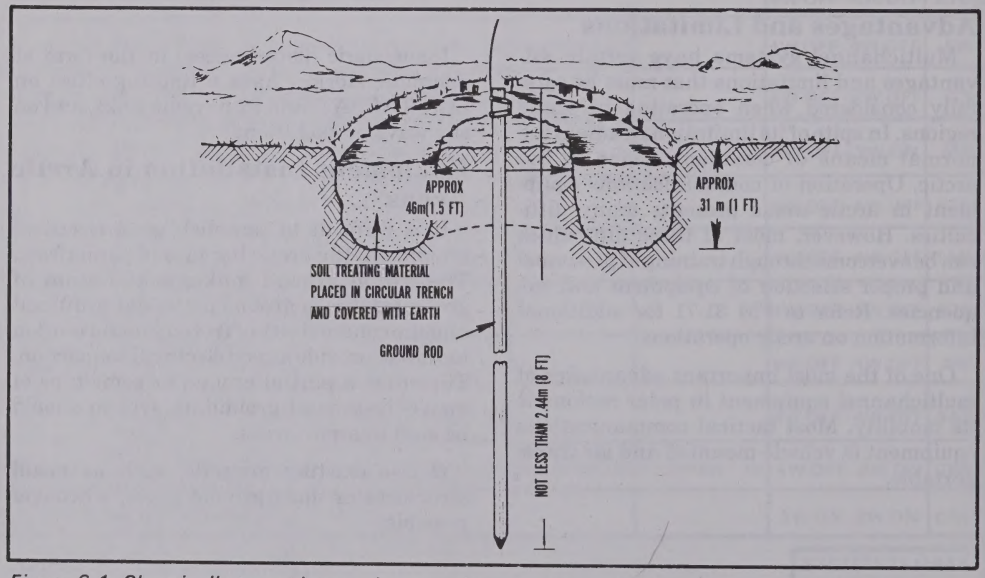


Figure 6-1. Chemically treated ground connection.

a must. In polar regions or other heavy ice loading areas, de-icing provisions should be included, if possible.

- Antennas with heating elements are available for use with some types of radio equipment, or in other cases, heating elements can be attached to existing antennas. Rigid conical shields of fiberglass-reinforced plastic (radomes) are available for some parabolic reflectors. These radomes often have heater wires embedded and are used to cover the feed device and reflecting surfaces of the parabolic reflectors. Antenna heating devices are usually automatically controlled by thermostats and relays.

- Antennas are designed to compensate for wind factors. The mesh designs of plane, corner, and the larger parabolic reflectors are designed to resist high wind factors. Generally, an antenna should have as wide a mesh as is electrically possible. High wind factors have a greater effect on parabolic reflectors, because it may shift or twist the reflector. Even a small twist is serious and will cause a large error in signal azimuth. Proper bracing and design can minimize parabolic twist, but it may be more advantageous to operate at lower frequencies and with wider beam widths.

□ Difficulty may be encountered in driving antenna guy anchors into ice, hardpan soil, or permafrost in arctic areas. The anchors supplied with the antenna system should be used if possible. If this is not possible, try to anchor the antenna guy lines to fixed objects such as trees, stumps, large rocks, or mountain pitons. Wrap a rope (at least 1.3 centimeters (½ inch) thick), cable, or piece of heavy wire, around the fixed object to anchor the guy lines (Figure 6-2).

- A quick-reaction antenna may also be used where it is not feasible to use guy anchors (stakes) because of hardpan soil, ice, or permafrost.

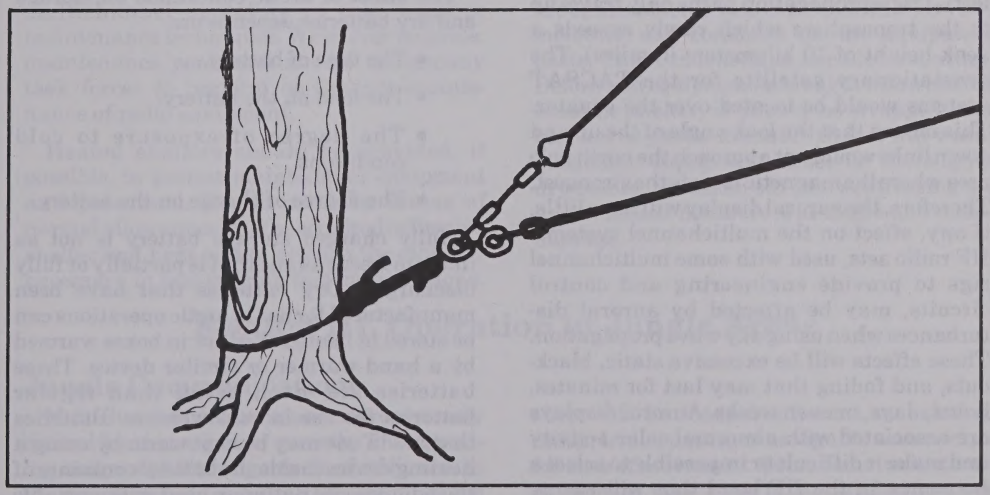


Figure 6-2. A fixed object such as a guy-anchoring device.

- Fuel drums filled with rocks or other ballast may be used effectively as antenna anchoring devices. This is done by cutting off each drum top, filling the drum with ballast and inserting a standard guy anchor or other type pole for attaching the antenna guys. The ballast is packed around the guy anchor or pole so it will stay in place. In areas where the average temperature remains below freezing for long periods of time, water may be used as a suitable ballast. Water will freeze solid in each drum, forming a stable and effective ballast. Water may also be poured around the base of each drum, freezing it to the ground so it will not move.

Auroral disturbances have negligible effect on the radio links of multichannel systems. Auroral displays are characterized by wide variations from normal in the state of the ionosphere. A normal LOS radio propagation path rarely exceeds heights of 15 meters (50 feet). Tropo propagation paths only travel up to the troposphere which rarely exceeds a peak height of 10 kilometers (6 miles). The geostationary satellite for the TACSAT systems would be located over the equator. This means that the look angle of the up and down links would not approach the north pole area where the magnetic force is the strongest. Therefore, the auroral display will have little, if any, effect on the multichannel systems. HF radio sets, used with some multichannel rigs to provide engineering and control circuits, may be affected by auroral disturbances when using sky wave propagation. These effects will be excessive static, blackouts, and fading that may last for minutes, hours, days, or even weeks. Auroral displays are associated with abnormal solar activity and make it difficult or impossible to select a frequency in the HF band that will ensure continuous communications.

Radio links of multichannel systems do not rely on sky wave propagation, so no serious difficulties should be encountered in selecting frequencies for use in arctic areas. However, many widely separated alternate frequencies should be provided for the HF circuits used for engineering and control.

Equipment Maintenance in Arctic Areas

Maintenance of communications equipment in extreme cold presents many problems. Blowing snow may freeze to dials and knobs or blow into the wiring and cause shorts and grounds. Cords and cables become brittle and easily damaged. All radio equipment and power units must be properly winterized.

The operation and maintenance of gasoline-driven power units become increasingly difficult as the temperature goes down. These units should be installed in heated shelters to ensure that they will operate when required.

The effect of arctic conditions on storage and dry batteries depends on:

- The type of battery.
- The load on the battery.
- The degree of exposure to cold conditions.
- The degree of charge on the battery.

A fully charged storage battery is not as likely to freeze as one that is partially or fully discharged. Dry batteries that have been manufactured for use in arctic operations can be stored in heated sheds or in boxes warmed by a hand warmer or similar device. These batteries are much better than regular batteries for use in cold weather. Batteries that are in use may be kept warm by using a heating device inside the battery container of the equipment. Batteries used with portable equipment may be carried next to the operator's body for warmth. Batteries no longer

serviceable for outdoor use may be used indoors.

Extensive shock damage may be caused to vehicular-mounted communications equipment by the jolting of the vehicle. Most synthetic rubber shockmounts become stiff and brittle in extreme cold and fail to cushion equipment.

Condensation, which may collect inside electronic communications equipment, can cause component failure. Changes in temperature will cause condensation on contacts and wiring.

When winterizing communications equipment, some parts may have to be replaced because they cannot function properly at low temperatures. Normal lubricants must be replaced with proper arctic lubricants, to prevent undue wear or poor operation.

Additional maintenance personnel may be needed to meet increased maintenance requirements in the arctic. However, this number can be kept to a minimum by training multichannel operators in cold weather maintenance techniques. Whenever possible, maintenance personnel should accompany task forces to perform on-the-spot maintenance of radio equipment.

Heated shelters should be provided, if possible, to protect maintenance equipment and personnel. Repair vans in excess of normal allowances may be required to furnish shelter and heat and to provide the mobility necessary in fast-moving tactical situations.

Moisture from the breath may freeze on switch buttons and perforated cover plates of microphones, thereby rendering the microphones inoperative. If standard covers are not available, a suitable cover can be improvised from thin rubber, cellophane, or cloth such as rayon or nylon fabric.

Metals in communications equipment contract differently in extreme cold, which may cause binding or locking of mechanical trains. Plugs, jacks, keys, shafts, bearings, dials, and switches are subject to malfunctioning because of this difference in the amount of contraction.

Most communications equipment employing vacuum tubes, such as transmitters and power supplies, generate heat when in operation. As the air inside the equipment cools, it contracts and draws cold air into the equipment from the outside. This is called breathing. When equipment breathes and subzero air comes in contact with it, the glues, plastic, and ceramic parts of the set may cool too rapidly and break. When cold equipment is brought suddenly into contact with warm air, moisture will condense on the equipment parts. This condensation is called sweating. Before cold equipment is brought into a heated room or shelter, it should be wrapped in a blanket or parka to ensure that it will warm gradually. Equipment must be thoroughly dry before it is taken out into subfreezing air or condensed moisture will freeze and cause damage.

Section III. Operation in Jungle Areas

Jungle Communications

Multichannel communications are seriously limited by dense jungle growth. The operating range of short-range, tactical radio sets in the jungle varies from 10 to 60 percent of the normal range. Larger, more powerful radio sets will usually be used in rear areas, and sites will be located adjacent to existing roads, trails, paths, or navigable water ways for ease of movement. Some communications equipment may have to be airlifted to sites that cannot be reached by surface vehicles.

Multichannel equipment and the field radio sets used for coordination and support of field operations in the jungle must be given great care because of damage resulting from heat, moisture, fungi, or insects. Refer to FM 90-5 for additional information on jungle operations.

Jungle terrain is usually conductive enough to provide for adequate grounding. The ground rod and ground cable provided with the equipment are adequate for proper grounding in most cases.

Long-Range Multichannel Systems

Tropo and TACSAT multichannel systems can provide dependable communications in a jungle environment. However, the antennas must be clear of obstacles and vegetation.

LOS Multichannel Systems

LOS, both conventional and microwave, multichannel systems can provide adequate communications in a jungle environment as long as the antennas can be positioned high enough to ensure a LOS path between transmitting and receiving antennas.

Cable and Wire

Because of dense vegetation, cable and wire trunks can be used in jungle operations but communications will still consist primarily of high powered radio systems and multichannel systems. Multichannel systems linked by cable will be limited to trails and roads in the area along which cable may be laid. Field wire will be used as much as possible to tie in the subscribers. Wire and cable are less subject to detection, deterioration, and destruction when suspended from trees. However, wire and cable are even less secure in the jungle because of the constant danger of enemy infiltration and wire tapping. Enemy infiltrators also pose an ambush threat to wire maintenance crews.

Equipment Installation in Jungle Areas

The following rules are useful guides when siting radio antennas and for improving radio communications in the jungle.

- Antennas should be located on hills above the jungle growth.

- Antennas should be located in a clearing that extends at least 100 yards from the antenna in the direction of the distant station.

- Antennas should be located as high as possible, especially when the antenna site is located directly behind an intervening terrain mask. If feasible, locate the radio equipment within one coaxial cable length of the antenna.

- Antennas should not be located in narrow valleys or between ridges or stretches of high jungle growth.

- Antenna cables and connectors should be kept off the ground to lessen the effects of moisture, fungi, and insects. This also applies to power and telephone cables. Insects can damage insulation on cable and wire. Fungi and moisture may cause corrosion, deterioration, grounding, poor contact, and other undesirable effects to connectors and wire, and to power cable and other types of communication cable.

- Vegetation, particularly when wet, will act much like vertically polarized antennas and absorb much of a vertically polarized radio signal. Therefore, horizontally polarized antennas should be used if possible.

□ Some jungle ground may be too soft to permit proper installation of the guy anchors. If available, use longer than standard lengths or use a screw-type anchor (Figure 6-3). If neither is available, use the larger vegetation in the area as guy-anchoring devices (Figure 6-2).

Jungle growth must be cleared from antenna sites. If an antenna touches foliage, the signal may be grounded, especially during the rainy season.

When mobile shelters are not available, tents or temporary shelters can be used to house communications equipment. Floors should be built in these shelters to keep equipment off the damp ground and away from moisture, fungi, and insects. These shelters should be constructed so that air can circulate freely.

Equipment Operation in Jungle Areas

Tropical rains, heat, fungi, and insects are all major problems in the operation of multichannel radio systems. Therefore, effective operation of communications equipment in the jungle depends on the training, resourcefulness, and perseverance of the individual operators.

Equipment Maintenance in Jungle Areas

Because of moisture and fungus growth, maintenance of multichannel equipment in tropical climates is more difficult than in temperate climates. The high humidity causes condensation to form on the equipment. This is especially true when the temperature of the equipment becomes lower than the surrounding air. To minimize this condition, keep equipment turned on or place lighted electric bulbs near the equipment.

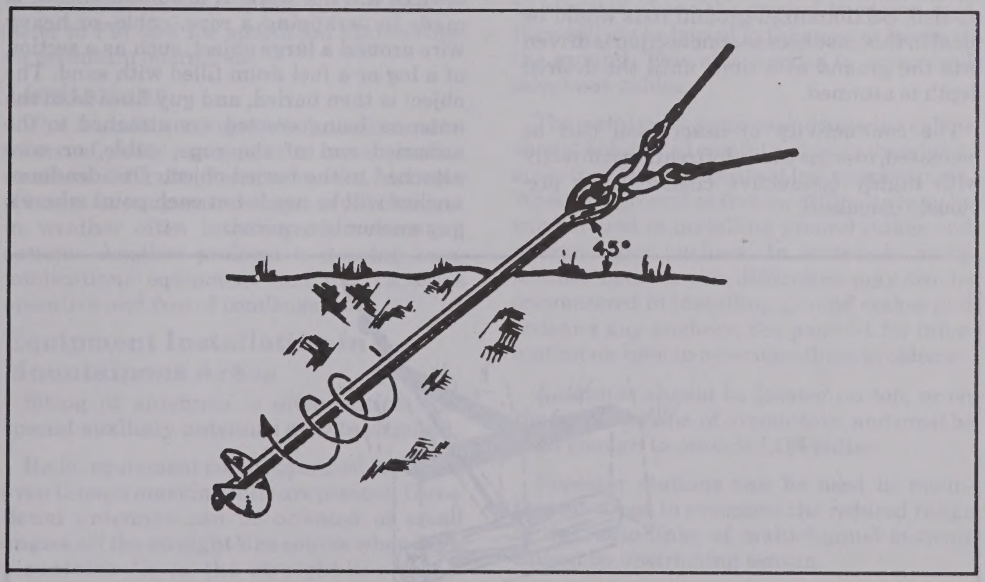


Figure 6-3. Screw-type guy anchor installation.

Section IV. Operation in Desert Areas

Desert Communications

Multichannel systems are usually the primary means of communication for military operations in the desert. They can be employed effectively in desert climate and terrain. They also furnish the highly mobile means necessary for operating in a fluid situation. For the same reasons, cable and wire are of little value for trunk communications. Refer to FM 90-3 for additional information on desert operations.

Electrical Grounds

Desert terrain provides poor electrical grounds, so grounding plates should be used when possible. A grounding plate is a plate of conducting material buried in the earth to serve as a grounding device.

An effective electrical ground may also be attained by locating communications equipment near an oasis or subterranean water, but a longer than standard ground rod will be needed. Sectionalized ground rods would be ideal in this case because one section is driven into the ground at a time, until the desired depth is attained.

The conductivity of desert soil can be increased, in some cases, by treating it directly with highly conductive chemicals as previously discussed.

Antennas

Radio antennas should be located on the highest ground available for best results in the desert.

Desert terrain is particularly soft, loose, and sandy. It will be difficult to find a place in the desert with soil conditions firm enough to permit proper installation of standard guy anchors. At times, guy anchors longer than standard length may be used effectively to anchor an antenna in desert soil.

Trees and other vegetation are normally very scarce in desert areas. However, if present, they may be used along with large rocks as antenna anchoring devices (Figure 6-2). Also, screw-type anchors may be effective, because they offer a slight advantage over standard guy anchors in loose desert soil.

A deadman anchor (Figure 6-4) may be effective when other types of guy-anchoring devices will not work. A deadman anchor is made by wrapping a rope, cable, or heavy wire around a large object, such as a section of a log or a fuel drum filled with sand. The object is then buried, and guy lines from the antenna being erected are attached to the unburied end of the rope, cable, or wire attached to the buried object. One deadman anchor will be needed at each point where a guy anchor is required.

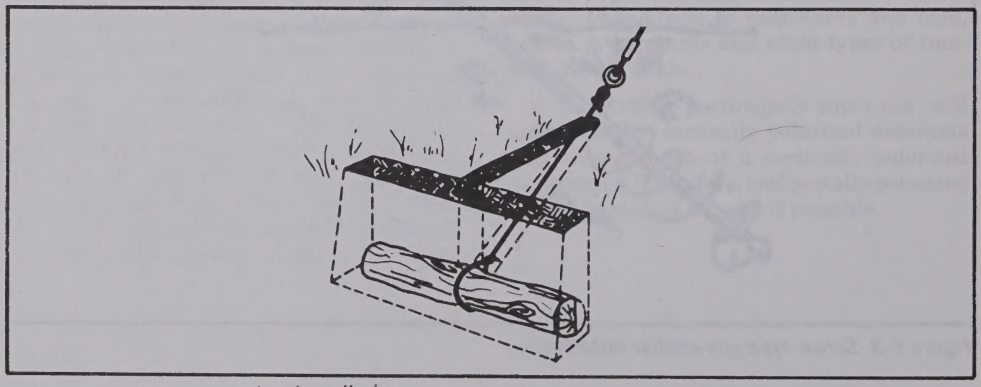


Figure 6-4. Deadman anchor installation.

Equipment Operation in Desert Areas

The maintenance problem is increased because of the sand, dust, or dirt that enters multichannel equipment. Sets with servomechanisms are particularly affected.

The best protection for communications equipment in desert areas is provided by mobile shelters. These shelters are practically dustproof, and sand-proof and have built-in ventilation and air-filtering systems. When mobile shelters are not available, tents and other types of temporary shelters should be erected. To reduce maintenance downtime on equipment that is not shelter-mounted, keep the equipment in its dustproof container as much as possible.

Equipment Maintenance in Desert Areas

Preventive maintenance checks should be made frequently, giving special interest to the cleaning and lubrication of equipment since dust, sand, or dirt produces grit that can damage the equipment.

Section V. Operation in Mountainous Areas

Mountainous Communications

In mountainous regions, normal maneuver is restricted and concealment is enhanced. Detailed planning, special training, and added equipment may be required to maintain effective communications in this type of terrain. Refer to FM 90-6 for additional information on mountain operations.

Limitations

The installation, operation, and maintenance of radio equipment in mountainous areas is difficult. Terrain masks, extreme changes in temperatures, and rapid changes in weather often interfere with communications. Another problem is keeping communications equipment and dry batteries operative and free of condensation.

Equipment Installation in Mountainous Areas

Siting of antennas is often critical and special auxiliary antennas may be required.

Radio equipment can be operated, at times, even though masking hills are present. Directional antennas can be oriented at small angles off the straight-line course when high mountains lie in the straight-line transmission path. Valleys and gaps can be used for transmission paths between mountains.

When siting a radio station directly behind a high, intervening mountain mask, the antenna should be located on the highest ground possible. The antenna cables should be elevated above the ground to ensure that they will not be buried in the snow or frozen to the ground. This also applies to power and telephone cables.

The metal mast sections and antenna cables should be handled carefully, during the winter, since they become brittle at low temperatures. When the ground is frozen, difficulty may be encountered in installing ground stakes and antenna guy anchors. In extremely rocky mountainous terrain, difficulties may also be encountered in installing ground stakes and antenna guy anchors. See page 6-1 for information on how to overcome these problems.

Antennas should be located on top, or on the forward slope, of a mountain, and must be high enough to provide LOS paths.

Repeater stations can be used in mountainous areas to overcome the reduced range of the radio links of multichannel systems caused by obstructing terrain.

□ The radio portions of multichannel systems should be located on high peaks to improve LOS transmission.

□ To solve special communication problems, aircraft may be used to relay single channel messages between radio stations that cannot communicate with each other. In this case, the ground radios must be compatible with the radios on board the aircraft.

□ Relay stations located at critical points will provide communications between terminal stations. This will reduce the length of each radio link and increase the S/N ratio. However, the use of relay stations will increase the total amount of equipment and personnel used. This additional equipment adds to the transportation difficulties and produces a requirement for an increased number of specialized technicians to install, operate, and maintain the communications equipment.

Skid chains should be used on vehicles operating on unpaved roads, regardless of the weather conditions. Personnel should be well trained in the use of ropes and pulleys. In hauling or raising and lowering equipment in mountainous areas, the equipment must be well packaged to prevent damage.

Cable and Wire Communications

Since the rate of military advance is normally slower in mountainous terrain, cable or wire trunk circuits can be used effectively. If extensive wire and cable trunks are required, the unit's organic capability may have to be increased.

Chapter 7

Field Expedients

Section I. Equipment Problems

General

A field expedient is an action that can be taken by personnel to maintain, facilitate, or expedite communications under unusual conditions. These conditions may occur due to normal wear or use of equipment, accidental damage, or hostile action. Using field expedients is a matter of common sense and ingenuity on the part of personnel immediately concerned. Nuclear weapons mitigation techniques for equipment need to be implemented, to the greatest extent possible, into daily operations.

Use of Printed Material

Signal TBs are commonly used in field operations. They suggest methods of overcoming equipment problems. Usually, they are used only until final publication of MWOs. DA Pam 310-1 lists published Signal TBs and MWOs.

Section II. Connections and Antennas

Protection for Coaxial Couplings

An effective protective covering for coaxial couplings is 3/4-inch nonadhesive polyethylene rubber and resin composition tape. Coaxial couplings protected by this tape can be submerged in water or subjected alternately to freezing and thawing temperatures without adversely affecting transmission qualities. The use of ordinary friction tape is unsatisfactory.

Antennas

The following are some of the expedients that may be used in installing antennas:

- Install antennas in a tree, on a building, house, or similar structure in an emergency.
- Use field wire, rope, or any similar material to replace lost or damaged guy wires.
- Use a shorter mast than is normal where the site is located at high elevations. This facilitates maintenance, orientation, and changes in antenna settings which may be required to change the operating frequency.
- Use a standard dipole antenna that is cut to proper length. However, this reduces the gain and directivity due to the absence of reflector and director elements.

Quick-Reaction Antennas

Quick-reaction antennas (Figure 7-1) are generally used as time saving devices. Use of a quick-reaction antenna depends on the tactical situation and the location of the shelter. Field fabrication of quick-reaction antennas is usually restricted to the use of one or two mast sections. Experimentation is necessary to come up with the best quick-reaction arrangement for the equipment being used. Normally, the configuration that gives the fastest on-the-air condition is preferable. A quick-reaction antenna may be used where it is not feasible to use stakes because of pavement, blacktop, or hardpan soil. A quick-reaction antenna may also be used where sufficient guy cable clearance is not available. Some mobile shelters come with quick-reaction antenna mounts, provide fast on-the-air conditions and are used until standard antennas are erected. The quick-reaction antennas are sometimes called shotgun antennas or bumper mount or machine gun mount. All three types are hasty forms of quick-reaction antennas. Allowing for transmission paths must be considered in using quick-reaction antennas the same as when using standard antennas.

Storage of Antenna Guy Wires

Antenna guy wires may be stored on a 1- by 4- by 24-inch board by making semicircular cuts at each end of the board and winding the guy wires around the board. The guy wire lengths may be indicated on the board and several guy wires may be wound on each board. These boards may be made to fit in the appropriate antenna parts case. This will keep the guy wires from becoming entangled and make it easier to locate and identify them.

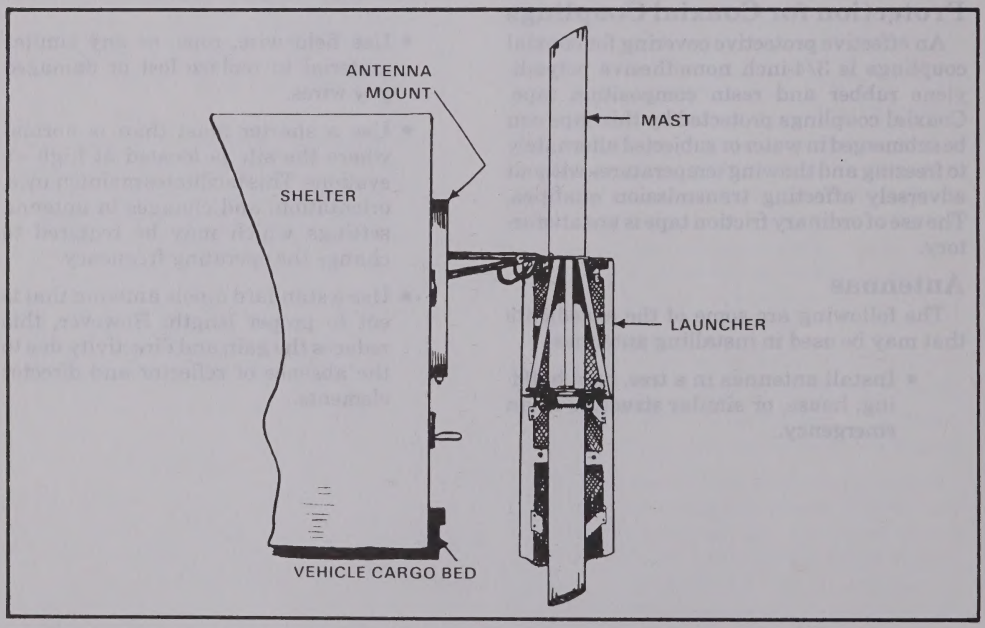


Figure 7-1. Typical quick-reaction antenna mount.

Section III. Power Source Expedients

Power Generators

Power generators are the source of power for your assemblage. However, they may also be the source of much trouble. Not only are they very noisy, there are serious safety hazards to be avoided.

Power Unit Noise Reduction

The procedure outlined below is designed to reduce power unit noise by approximately 90 percent.

Construct a dugout with sufficient space for maintenance and ventilation.

Locate the dugout on a slight rise or hill so water will be drained off. Construct drainage ditches from the low side of the dugout.

Reinforce the sides of the dugout with sandbags or wooden or steel framework to provide support and to prevent cave-ins. Be sure to leave sufficient space between the sides and generators to allow air circulation.

Erect a roof of available material to provide protection from the weather. Allow space for a ventilator shaft to carry away exhaust fumes.

Drape empty sacks or canvas along the roof overhang to muffle generator noise.

Camouflage the dugout to match the surrounding terrain.

Generator Safety

Because generators run on flammable fluids (gas, diesel fuel), and produce electricity, some serious safety factors exist. Without proper installation procedures, an operator could be seriously injured or even killed. The following is a list of items to be checked when installing a power unit:

- Establish a fire point with proper equipment.
- Ground the power unit properly prior to starting.
- Perform maintenance IAW proper TMs.
- Install power units in a level position.

After the power unit is installed and operational, go over all the safety checks again to ensure that all safety areas have been covered. Refer to your unit SOP and appropriate TMs for more detailed information.

Section IV. Operational Expedients

Operational Capabilities

Most multichannel radio operators who have been on the job for a long time have learned some tricks-of-the-trade that will improve their operational capability. This section will give some accepted methods used by the old timers to enhance their communications effectiveness. Be sure to check your unit SOP and the appropriate TMs before trying the methods in this section.

Improvement of Marginal Multichannel Systems

Terrain can seriously distort the antenna radiation pattern so that a weak signal is received instead of a strong one. Often a stronger signal can be obtained by trial and error methods. Experiment with using indirect radio paths utilizing adjacent obstacles such as high mountains. In Figure 7-2A, antennas are oriented for a direct path and a weak signal is obtained because of the intervening hills and reflections by the adjacent obstacle. In Figure 7-2B, antennas are oriented for an indirect path which results in a stronger signal.

Operating sites should be selected as outlined in Chapter 2. Sometimes a site will not provide the best LOS and marginal systems may result. To improve marginal systems:

- Tighten cable couplings and connections.
- Retune all transmitters and receivers in the system.
- Check antennas for proper polarization/ orientation.
- Change antennas height and location.

Transmission and Reception

After an adequate site has been selected and the antenna has been properly oriented, the signal level at the receiver will be proportional to the strength of the transmitted signal.

If a high-gain antenna is used, a stronger signal will be obtained. Most high-gain antennas at the higher frequencies use a parabolic reflector. Losses between the antenna and the equipment may be reduced by using a high quality transmission line, as short as possible, and properly matched at both ends.

Use of Obstacles to Obtain Long Transmission Paths

Traditionally, LOS systems in VHF, UHF, and SHF ranges have been considered satisfactory only when the path was unobstructed and stations were close enough, or sufficiently elevated, to be within radio LOS. Both range and reliability were thought to have a maximum limit. However, recent experience indicates that satisfactory communications usually can take place over a range greater than the radio LOS, and that range and reliability may be improved on long systems by an elevated obstacle in the signal path.

When a high, sharp mountain ridge near the center of a path, between the transmitter and receiver, diffracts a transmitted signal over its peak and propagates it down the opposite side, it is called knife edge effect or knife edge diffraction. Long transmission paths relatively free from fades and with improved signal levels have been observed using this mode of propagation. Paths near or

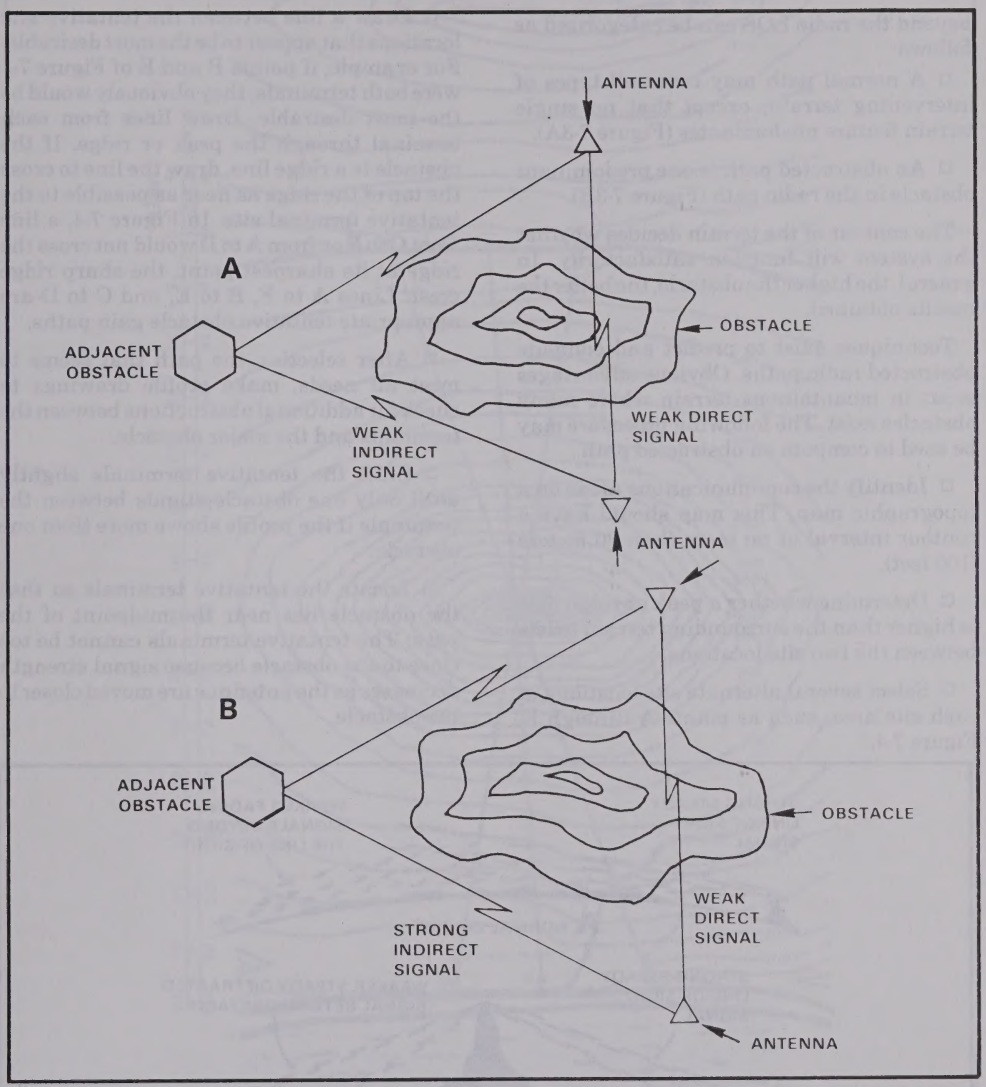


Figure 7-2. Antenna orientation.

beyond the radio LOS can be categorized as follows:

□ A normal path may cover all types of intervening terrain, except that no single terrain feature predominates (Figure 7-3A).

□ An obstructed path is one predominant obstacle in the radio path (Figure 7-3B).

The contour of the terrain decides whether the system will function satisfactorily. In general, the higher the obstacle, the better the results obtained.

Techniques exist to predict and compute obstructed radio paths. Obvious advantages occur in mountainous terrain where many obstacles exist. The following procedure may be used to compute an obstructed path.

□ Identify the communications areas on a topographic map. This map should have a contour interval of no more than 30 meters (100 feet).

□ Determine whether a peak or ridge that is higher than the surrounding terrain exists between the two site locations.

□ Select several alternate site locations in each site area, such as points A through F, Figure 7-4.

□ Draw a line between the tentative site locations that appear to be the most desirable. For example, if points B and E of Figure 7-4 were both terminals, they obviously would be the most desirable. Draw lines from each terminal through the peak or ridge. If the obstacle is a ridge line, draw the line to cross the top of the ridge as near as possible to the tentative terminal site. In Figure 7-4, a line from C to F or from A to D would not cross the ridge at its sharpest point, the sharp ridge crest. Lines A to F, B to E, and C to D are appropriate tentative obstacle gain paths.

□ After selecting the path that seems to meet all needs, make profile drawings to check for additional obstructions between the terminals and the major obstacle.

□ Shift the tentative terminals slightly until only one obstacle stands between the terminals if the profile shows more than one obstacle.

□ Locate the tentative terminals so that the obstacle lies near the midpoint of the path. The tentative terminals cannot be too close to the obstacle because signal strength decreases as the antennas are moved closer to the obstacle.

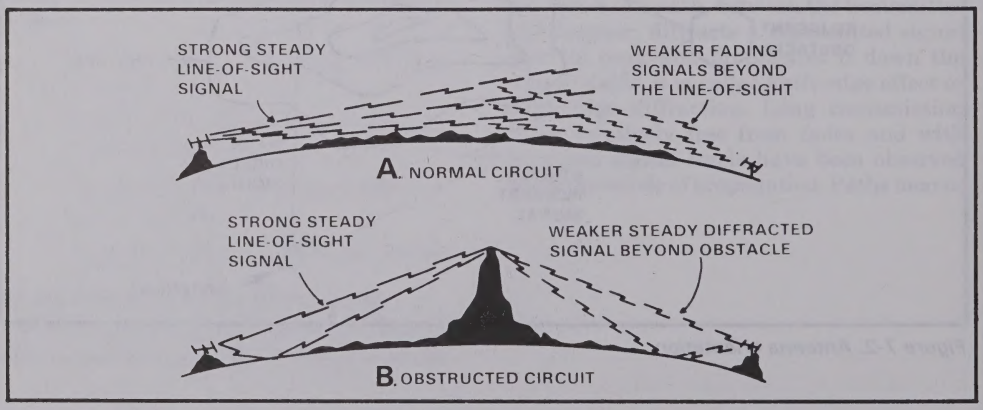

STRONG STEADY LINE-OF-SIGHT SIGNAL
WEAKER FADING SIGNALS BEYOND THE LINE-OF-SIGHT
A. NORMAL CIRCUIT
STRONG STEADY LINE-OF-SIGHT SIGNAL
WEAKER STEADY DIFFRACTED SIGNAL BEYOND OBSTACLE
B. OBSTRUCTED CIRCUIT

Figure 7-3. Use of an obstruction to establish an obstacle gain path.

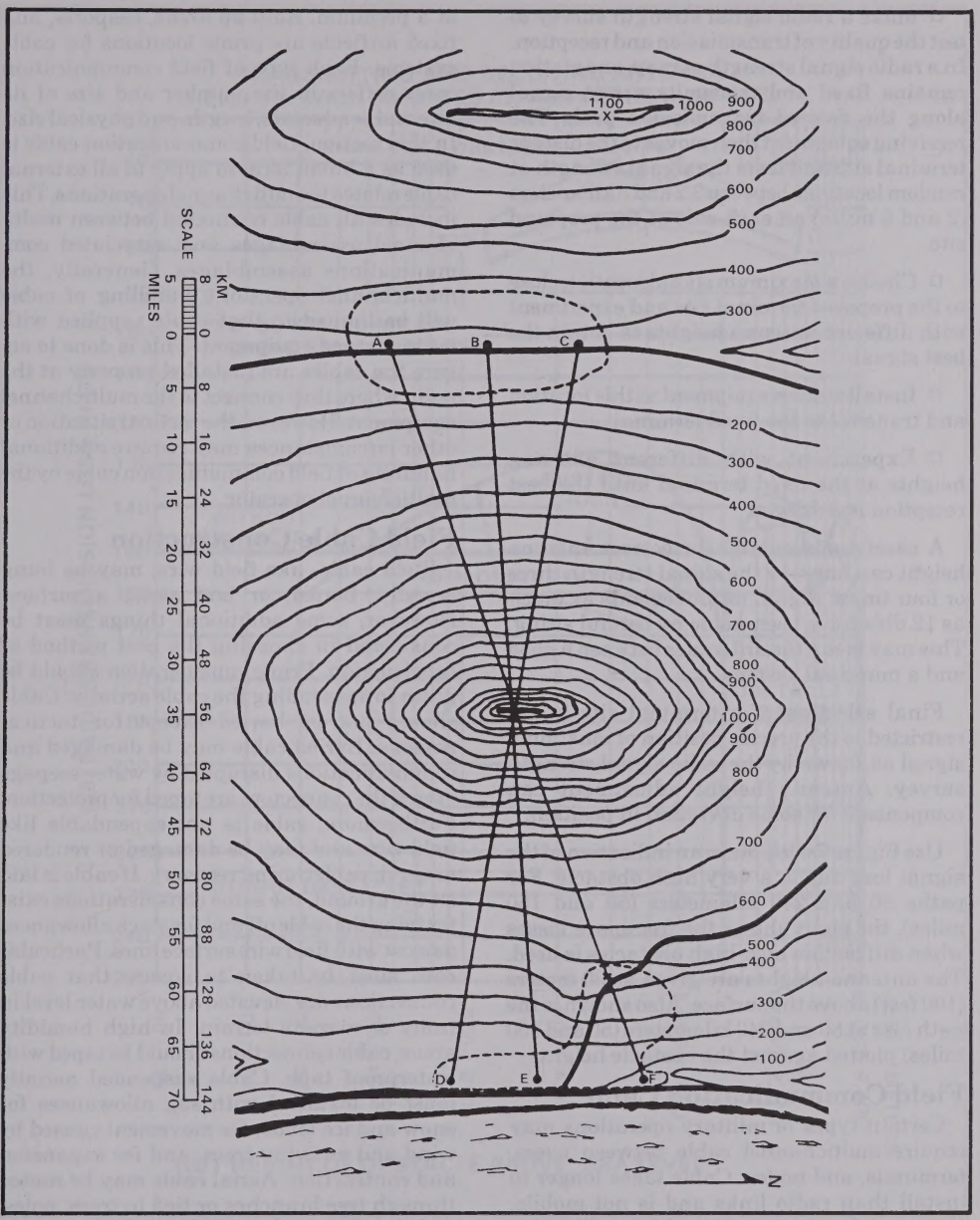


Figure 7-4. Selecting an obstacle gain path.

□ Make a radio signal strength survey to test the quality of transmission and reception. In a radio signal strength survey, one station remains fixed and transmits a test signal along the desired transmission path. The receiving equipment then moves to the distant terminal site and tests the signal strength at random locations between 3.2 and 8 kilometers (2 and 5 miles) on each side of the proposed site.

□ Choose a maximum signal location close to the proposed terminal site and experiment with different antenna heights to obtain the best signal.

□ Install station equipment at this location and transmit to the fixed terminal.

□ Experiment with different antenna heights at the fixed terminal until the best reception is achieved.

A careful survey and the correct antenna height can improve the signal strength three or four times. Signal improvements as much as 12 db's have been made by careful siting. This may mean the difference between a good and a marginal system.

Final selection of a terminal site is not restricted to the precise position of maximum signal as shown by the radio signal strength survey. Antenna height adjustment can compensate for some deviation in position.

Use Figure 7-5 to obtain an indication of the signal loss due to a very high obstacle. For paths 80 and 240 kilometers (50 and 150 miles), the chart shows the free-space losses when diffraction over high obstacles is used. The antenna heights are given as 30 meters (100 feet) above the surface. Also shown is the path loss at 80 and 240 kilometers (50 and 150 miles) plotted against the obstacle height.

Field Communication Cable

Certain types of military operations may require multichannel cable between users, terminals, and nodes. Cable takes longer to install than radio links and is not mobile. However, it is less vulnerable to EW and eavesdropping. Cable use is feasible when terminals involved are stable and security is at a premium. Built-up areas, seaports, and fixed airfields are prime locations for cable systems. Each type of field communication cable differs in the number and size of its internal conductors, length, and physical size. In this section, field communication cable is used as a broad term to apply to all external cable related to multichannel operations. This includes all cable connected between multichannel assemblages and associated communications assemblages. Generally, the multichannel operator's handling of cable will be limited to that cable supplied with multichannel equipment. This is done to ensure the cables are installed properly at the point where they connect to the multichannel equipment. However, the tactical situation or other circumstances may require additional handling of field communication cable by the multichannel operator.

Field Cable Construction

Field cable, like field wire, may be hung aerially, buried, or laid along a surface. However, some additional things must be considered in choosing the best method of construction. Prime consideration should be given to suspending the cable aerially. Cable should not be buried except for tactical reasons. Buried cable may be damaged and communications disrupted by water seepage even if the connectors are taped for protection. Furthermore, cable is not expendable like field wire and may be damaged or rendered unserviceable during recovery. If cable is laid on the ground, the same considerations exist for tying the cable off and for slack allowances as exist with field wire surface lines. Particular care must be taken to ensure that cable connections are elevated above water level in rainy or marshy terrain. In high humidity areas, cable connections should be taped with waterproof tape. Cable suspended aerially must be installed with sag allowances for snow and ice loads, for movement caused by wind and swaying trees, and for expansion and contraction. Aerial cable may be routed through tree branches or tied to trees, poles, or other supports with field wire or rope. Aerial cable should be kept clear of power lines. A tension bridge should be installed at

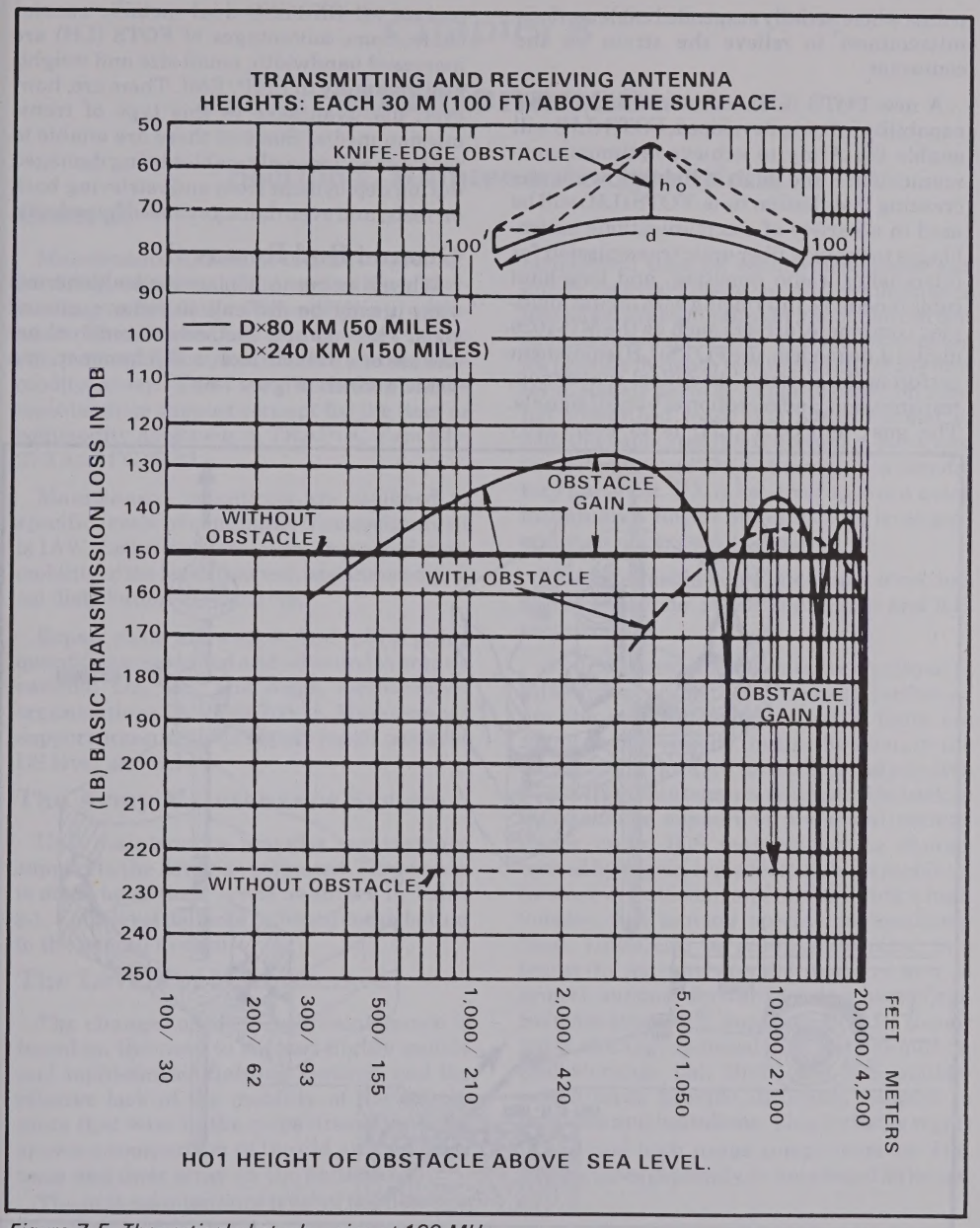


Figure 7-5. Theoretical obstacle gains at 100 MHz.

points where aerially suspended cable sections interconnect to relieve the strain on the connector.

A new FOTS (LH) communications cable capability is being developed. FOTS (LH) will enable the Army to achieve optimum communication and high reliability while decreasing installation time. FOTS (LH) will be used in a variety of communications assemblages to provide fiber optic transmission for intershelter, radio remoting, and long-haul cable functions. Interfacing with digital multiplex combiners/drivers such as the MD-1026 digital data modem, the FOTS (LH) equipment performs the electrical to optical conversion, transmission, and reception of optical signals. The goal of FOTS (LH) is to eventually replace all CX-11230 dual metallic coaxial cable. Some advantages of FOTS (LH) are increased bandwidth, small size and weight, and immunity to EMP/EMI. There are, however, disadvantages to this type of transmission media. Some of these are unable to repair or splice easily, cables being damaged during deployment from and retrieving back on reels, and even damage caused by rodents.

Ground Rod Removal

When it is time to displace the multichannel van, it may be difficult to remove ground rods. Three simple methods of removal are the use of a vehicle jack, a slip hammer, or a vehicle winch (Figure 7-6).

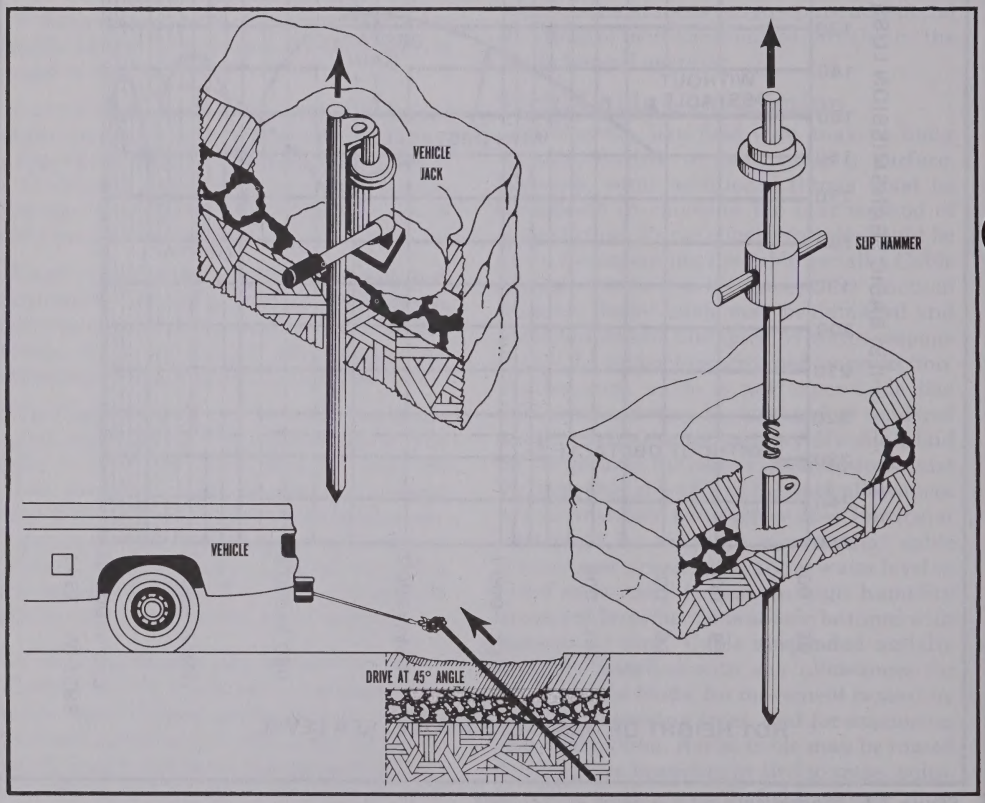


Figure 7-6. Removal of a ground rod.

Chapter 8

Maintenance

Section I. Maintenance Operations

General

Maintenance operations include inspecting, servicing, adjusting, aligning, repairing, overhauling, rebuilding, and modifying equipment. These operations are specified in the equipment publications for each item or commodity group. They vary according to the maintenance support concept for the item or commodity as shown in TRADOC Pam 525-27-3 and FC 29-2J.

Maintenance operations are assigned to specific levels of command. The assignment is IAW the primary mission, characteristics, mobility of the level involved, and the economical distribution of resources.

Repair parts allowances and initial guide quantities are selected and allocated to organizational DS, GS, and depot maintenance organizations IAW AR 700-18. Maintenance support organizations supply repair parts for DS level and below.

The Army Maintenance System

Unit maintenance provides maintenance support to the Army's equipment. The system is made up of three levels as shown in Table 8-1. Each level makes a different contribution to the overall system.

The Levels of Maintenance

The change to three-level maintenance is based on the need to support highly mobile and sophisticated fighting systems, and the relative lack of the mobility of the old GS units that were in the corps area. Figure 8-1 shows a comparison of the old and new systems and their array on the battlefield.

The unit maintenance level of the new system corresponds to the operator, organizational, and AVUM categories of the old system. Maintenance is characterized by a quick turnaround time on replacement parts and minor repairs. Operators and maintenance personnel make maximum use of built-in test equipment to support BDAR. Systems mechanics provide in-depth technical skill at the unit level. Repair parts stockage is based on combat prescribed load lists which consist of demand supported items desired in stock and those items required for stockage by a mandatory parts list. DX is used to support a quick turnaround. Repair times at this level generally do not exceed 4-6 hours.

The intermediate maintenance level has two orientations: IDS maintenance and IGS maintenance.

□ IDS maintenance units are employed at different locations, but the tasks performed are the same. IDS maintenance units are found in the brigade, in the division, in the corps, and in the EAC areas. Selected nondivisional IDS maintenance units provide backup maintenance support to divisional maintenance units. IDS maintenance is characterized by repair, replacement, high mobility, forward orientation, and maintaining a high volume, fast moving operational readiness float. Units can be readily organized into teams to support specific systems and to project support forward on the battlefield. Suitcase-type ATE supports BDAR. Repair parts stockage is based on a combat authorized stockage list. Divisional IDS maintenance units provide dedicated support to brigades and battalions. This includes repair of selected high usage components for DX. Repair times generally do not exceed 36 hours.

□ IGS maintenance units are located behind the corps and provide support to the theater supply system through repair of class VII and class IX items. Their work is production line oriented and is performed by modular units with commodity-oriented platoons in semifixed facilities. Teams may be added

Table 8-1. The three levels of The Army Maintenance System.

	Unit	INTERMEDIATE		Depot
		(Direct Support)	(General Support)	
WHO	• User	• Intermediate maintenance direct support units • Installation support maintenance shop	• Intermediate maintenance general support units • Installation support maintenance shops	• TDA activities • Industrial-type activities • Commercial contractors
WHERE	• Equipment location • Unit maintenance shops • Unit maintenance collecting point (UMCP)	• Mobile maintenance shops • Fixed shops in installations • Equipment location • Unit maintenance collecting point (UMCP) • Maintenance collecting point	• Semi-fixed maintenance shops • Installation maintenance shops • Equipment location on an exception basis	• Fixed plant-type facilities • On site on exception basis
WHAT	• Preventive maintenance checks and services (PMCS) • Inspections • Lubrication and cleaning • Preserving • Tightening • Minor adjustment • Replacement of piece parts • Recovery of unserviceables	• Diagnose and isolate faults on equipment/components & assemblies • Adjust, calibrate, and align components and assemblies • Operate a direct exchange activity • Light body repairs • Technical assistance • Evacuate unserviceables	• Diagnose and isolate faults on equipment, components & assemblies to the internal piece part level • Adjust, calibrate, align & repair components, assemblies and modules • Repair/modification of end items/components & assemblies to the internal piece part level • Heavy body, hull, turret, frame repair • Collection & classification of unserviceable class VII • Evacuate disposable material • Technical assistance	• Overhaul of end items/components, assemblies and modules to manufacturers tolerances • Repairs requiring special environmental facilities • Nondestructive testing of used parts • Inspections/modifications requiring extensive disassembly or elaborate test equipment • Cyclic overhaul and special maint programs • Manufacture of parts not otherwise obtainable
HOW	• Diagnosis & isolation of failures • Use of built-in test equipment, simple go-no go indicators installed • Instrumentation and external diagnostic/fault isolation devices	• Replacement of components & assemblies, modules and piece parts • Provide highly mobile maintenance support teams (MSTs) • Use of direct exchange (DX) and operational readiness float (ORF)	• Replace components, assemblies & modules and performance of repairs not requiring restoration to original manufacturers tolerances or specifications • Operate cannibalization point(s)	• Wholesale level direct exchange • Restoration of unserviceables to prescribed levels of serviceability • Modernization of serviceable assets
WHY	• Sustain materiel readiness	• Support using unit by repair and return of equipment to user	• Support of the theater supply system	• Support of the supply system

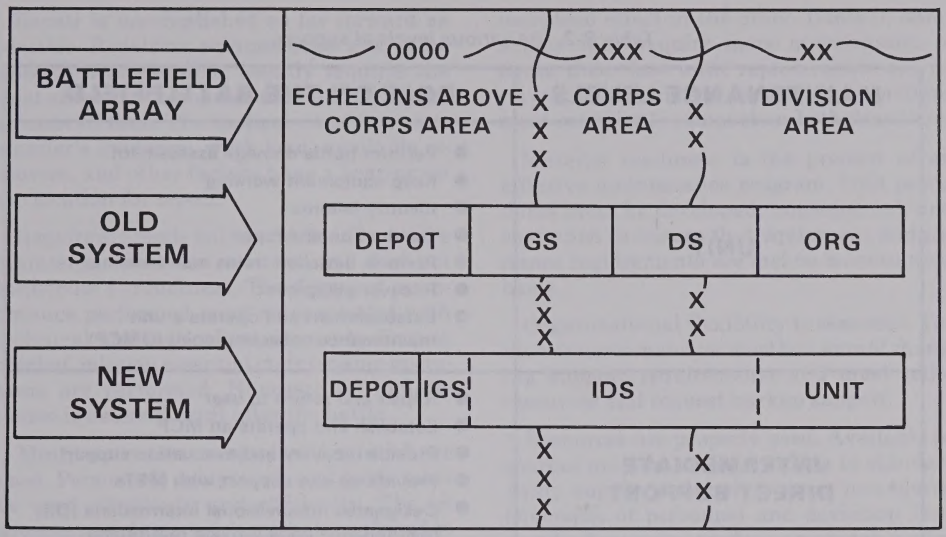


Figure 8-1. Old and New Army Maintenance Systems.

to provide an area support capability. GS-type ATE supports operations. IGS maintenance units do not have an authorized stockage list; however, they maintain a shop stock for assigned missions. The units maintain theater reserve stocks in overall support of theater requirements.

Depot maintenance at this level is production line oriented and is performed in support of the supply system. Work is done by special repair activities, US Army Materiel Command depot, and contractor personnel. The unit missions support overseas pre-positioning of materiel configured to unit sets, repair cycle float, and war reserve stocks. Repair parts supply support for depot maintenance is limited to items that support assigned maintenance missions.

Maintenance Role on the Battlefield

The maintenance system sustains the combat power which can be placed against the enemy. It influences the outcome of the battle by returning equipment to the combat unit while the battle is still being fought. Equipment which takes longer to repair contributes to the success of subsequent battles. Table 8-2 shows the role of the various levels of support.

Maintenance Allocation Chart

The MAC is usually published in the unit maintenance manual for a piece of equipment or as part of a combined category TM. The MAC remains the primary tool for assigning tasks under The Army Maintenance System. The MAC shows the lowest level authorized to do a specific task. It is part of the logistics support plan developed for each Army adopted item of equipment. The allocation of maintenance tasks is made on the basis of time, tools, and skills normally available at the location where the work is done.

Table 8-2. The various levels of support.

MAINTENANCE LEVELS	ROLE ON THE BATTLEFIELD
UNIT	• Perform battle damage assessment • Keep equipment working • Identify failures • Conduct on-site repair • Perform battalion trains maintenance • Recover equipment • Establishment and operate a unit maintenance collecting point (UMCP)
INTERMEDIATE DIRECT SUPPORT	• Repair and return to user • Establish and operate an MCP • Provide recovery and evacuation support • Provide on-site support with MSTs • Designated nondivisional intermediate (DS) maintenance units provide reinforcing support to divisional maintenance
INTERMEDIATE GENERAL SUPPORT	• Repair and return materiel to theatre supply system
DEPOT	• Repair and return items to stock • Provide support in theatre of operations

Maintenance Policies

Maintenance is a command responsibility. Commanders—

- Ensure equipment issued to the unit is serviceable and combat ready.
- Ensure equipment is properly used, maintained, and accounted for.
- Advise higher commanders of their equipment replacement and maintenance support requirements.
- Comply with instructions and procedures for preventive maintenance operations and training.
- Allocate sufficient time for performing preventive maintenance.
- Assign maintenance responsibility for each item of unit equipment to specific individuals.
- Investigate and take corrective action to prevent abuse of materiel.
- Maintain records of usage, maintenance, and modification of certain items of equipment as prescribed in applicable regulations and directives.
- Train maintenance and key personnel.

Repair is accomplished as far forward as possible. Repairing equipment on site, or as close to it as possible, usually requires the least amount of resources and takes the least amount of time. The tactical situation, commander's guidance, work load, available resources, and other factors have a bearing on the location for repair.

Repairs are made only as needed. Excessive maintenance wastes resources and does not contribute to readiness. The degree of maintenance performed must be consistent with technical and tactical requirements. During combat, mission essential maintenance operations are performed. Nonessential maintenance is deferred until after the battle.

Minimum resources required for the job are used. Personnel, equipment, and parts must be used effectively and efficiently. The resources saved on one job can be transferred to another.

Maintenance and supply are interdependent. A shortage in one may be offset by an increased effort in the other. Items in short supply may require more maintenance to make them last until replacements are received. Maintenance management actions must consider the impact on both functions.

Materiel readiness is the product of an effective maintenance program. Unit procedures must be developed, implemented, and sustained to ensure that equipment maintenance requirements are met on a continuous basis.

Organizational flexibility is essential. The maintenance manager must be aware of changing support requirements and must tailor resources and request backup support.

Resources are properly used. Available resources must be used according to standard Army supply and maintenance procedures. Diversion of personnel and deviation from standard procedures reduce maintenance effectiveness.

Section II. Preventive Maintenance Checks and Services

Maintenance

Preventive maintenance is the systematic care, inspection, and servicing of equipment to maintain it in servicable condition and prevent breakdowns. It is performed by operators and organizational maintenance personnel.

Operators perform only routine maintenance that can be performed by personnel with a limited technical background. Each appropriate TM covers these preventive maintenance measures in an operational checklist.

Organizational maintenance personnel provide maintenance backup support to the operator and are responsible for organizational maintenance that requires limited technical training. Each appropriate TM contains equipment performance checklists and other organizational maintenance information.

Responsibility

Commanders ensure that personnel under their command comply with procedures and instructions dealing with preventive maintenance and that they fill out the required maintenance records as required by DA Pam 738-750.

Preventive Maintenance Services

Equipment operators perform preventive maintenance services daily. The equipment is inspected and serviced IAW procedures outlined in the TM and DA Pam 738-750. Deficiencies and shortcomings that are not corrected by the operator, or that are corrected by replacement of parts, are recorded on appropriate maintenance forms as required by DA Pam 738-750.

Organizational maintenance personnel perform periodic services (inspections and services) prescribed by appropriate TMs. All deficiencies and shortcomings, as well as the corrective action taken for each, are recorded on an appropriate maintenance form as required by DA Pam 738-750. If repairs by a higher category of maintenance are required and appropriate, maintenance forms will be prepared and forwarded with the equipment to the supporting maintenance activity.

Electric Shock Hazards and Safety Precautions

High voltages are generally required in the operation of multichannel equipment. Death on contact or serious injury may result from these voltages if safety precautions are not observed. Operators and maintenance personnel must become familiar with the equipment manual before operating the equipment. They must comply with the warning published in the TM and posted on/or inside the equipment.

Whenever communications equipment uses high voltages, the operator should:

□ Avoid direct contact with high voltage or power connections.

□ Avoid contact with transmission lines and antennas that have radio frequency voltages.

□ Disconnect or turn off power source prior to performing maintenance on equipment.

□ Check the equipment manual for a list of components that contain high voltages.

□ Discharge all high voltage capacitors prior to performing maintenance.

□ Operate and perform maintenance on equipment employing hazardous voltages only (where possible) when another operator or repairman is present.

Section III. Troubleshooting Multichannel Systems

Troubleshooting Procedures

All multichannel operators must establish and follow standardized procedures for troubleshooting. This ensures timely restoration of equipment in the event of a system or circuit failure. Troubleshooting procedures appear under the maintenance section of most TMs. Operators should be aware of procedures in pertinent TMs restricting certain troubleshooting procedures during system operation.

A multichannel radio system consists of the following:

- Radio terminal sets.
- Radio relay sets.
- Multiplexing sets.
- Ringing equipment.

The system trouble can be sectionalized by testing:

- The radio system between terminal stations in both directions.
- The multiplexing system between terminals in both directions.

When the system trouble has been sectionalized, it must be localized to a defective item, such as:

- A defective transmitter in the radio system.
- A defective item of multiplexing equipment.

When the defective items of equipment have been localized, isolate the defective component in the item of equipment, such as:

- A defective fuse in the transmitter.
- A defective cable between the multiplexer and the radio.

The operator should correct the trouble and return the system to service. If the trouble cannot be corrected immediately, the operator should replace the defective item of equipment with an item of backup equipment and send the defective item to maintenance for repair.

A step-by-step procedure for sectionalizing system troubles is discussed in the following paragraphs. This procedure may vary slightly from one type of equipment to another type and is discussed here as a general guide only.

Step 1: The multichannel operators at both ends of the system work together to determine if a problem exists with the radios or antenna system. If the problem is found to be with the radio system, corrective action is taken to restore the radio system.

Step 2: If the radio system is operating properly, the operators at both ends of the system will check the cabling between the radio and the multiplexing equipment. If the cabling is defective, the operator will replace or repair it.

Step 3: If the cabling is good, the operators at both ends of the system will work together to determine if the problem is with the mux equipment. In this example, since the radio system and the cables interconnecting the radio/mux equipment are good, the mux equipment should be found defective. The operator with the defective mux equipment will replace it with backup equipment. This will restore the multichannel system to service. The operator will then follow established procedures in order to turn in the bad mux equipment for repair at the next higher category of maintenance.

Station Operation and Maintenance

Overall tests of communications channels include initial and periodic tests to assure serviceability. Adequate testing equipment is required at terminals and intermediate points to perform overall and sectionalizing tests. Under the supervision of the control facility, overall signaling, talking, and transmission tests from terminal to terminal should be made first. These are followed by sectionalizing tests between control facilities and, finally, between relay stations.

Tests on Trunks of Multichannel Systems

An SOP must be established to ensure orderly control of maintenance and other work for those long distance circuits which pass through several tests or mux and radio terminal stations in different areas.

Orderwire circuits often are built-in features of military multichannel equipment. The orderwires may be extended to orderwires of connected systems in circuit layout.

Maintenance personnel are required at all stations in a system to permit coordination of testing activities on long distance trunks and

transmission systems. Control and subordinate facility procedures must provide for orderly analysis of troubles and should designate responsibility for placing and maintaining systems and circuits in service. Once a trouble is located, corrective maintenance procedures must be carried out.

The CNCE/CSCE is the overall controlling element of all systems and circuits. The CNCE/CSCE directs all elements of a system in troubleshooting of a system when a problem arises.

Chapter 9

TRI-TAC Block III EAC Communications

Section I. TRI-TAC Block III

General

There is an urgent need to provide an integrated theater area communications system spanning all battlefield echelons from division and corps through EAC areas of operation. Changes to the present TRI-TAC communications architecture are necessary. It is essential that EAC tactical communications systems provide capabilities similar to the MSE corps and division area system.

AirLand battle doctrine demands changes in how the Signal Corps provides communications for tactical and theater Army operations. The need for increased flexibility, dispersability, mobility, and transportability at EAC agrees with the AirLand battle concept of a deeper, expanded, and integrated battlefield. Bringing MSE capabilities into EAC satisfies user mobility requirements and eliminates artificial communications boundaries between corps and EAC. However, there still remains a need for greater geographical communications coverage and an increased capability for supported units to disperse throughout the EAC area of operation. This establishes the need for many automatic switching nodes. Greater dispersion of supported units can be achieved and greater reliability and survivability of network traffic provided with the increased number of transmission paths and switching centers. (See Figure 9-1.)

Operational Characteristics

The TRI-TAC Block III tactical communications architecture is a digital, automatic, common-user switching network that provides mobile subscriber capabilities identical to corps and division capabilities. Block III provides an integrated communications network. TRI-TAC and MSE programs provide materiel resources for implementing required operational capabilities. The Block III structure consists of TRI-TAC Block III heavy battalions (DGM based) and Block III light battalions (MSE based). The TRI-TAC Block III system will provide—

- MSE compatible nodal circuit switching including flood search routing, automatic subscriber affiliation, and MSRT subsystem features. This is done by modifying the AN/TTC-39A TRI-TAC circuit switch to an AN/TTC-39D.
- Automated network control features.
- Unit level extension switches.
- Internodal and intranodal radio transmission.
- NRI capabilities.
- Formal/informal record traffic service on a dial up basis.

TRI-TAC Block III architecture features include—

- Communications assemblages.
- Wire subscriber access service.
- Interface capabilities with common US and NATO member country commercial telephone systems.
- Local loop service.
- The ability to serve about 25 subscribers from each radiotelephone access location.

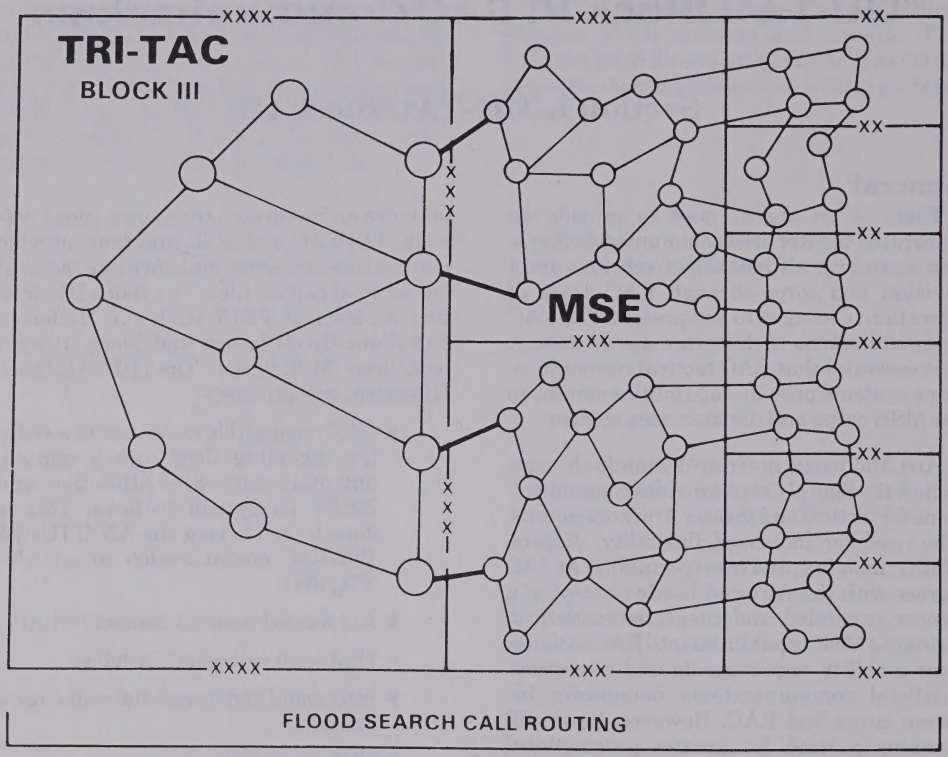


Figure 9-1. TRI-TAC Block III integrated theater network.

- A minimum number of vehicles with mounted communication assemblages for each nodal configuration.
- A preferred crew size of three for each communication assemblage.
- An omnidirectional RF link capability.
- Wire and cable used locally.
- Separation of the wire subscriber access equipment from its associated radio access equipment for increased survivability of users.
- Digital subscriber loops at a data rate of 16 kb/s or a multiple thereof.
- The ability to convert to a totally wireless CP.
- Operation in a dismounted configration (building and tent).

The Block III architecture converts the EAC communications network from 32 kb/s to 16 kb/s. Characteristics found in the original TRI-TAC/INTACS architecture are retained, including joint service interoperability features, interface capabilities, large subscriber and trunk switching facilities, and high volume transmission paths. The Block III architecture eliminates artificial communications boundaries by allowing for migration of hardware between battlefield echelons and by providing identical call routing features at all echelons.

TRI-TAC Block III performance features include—

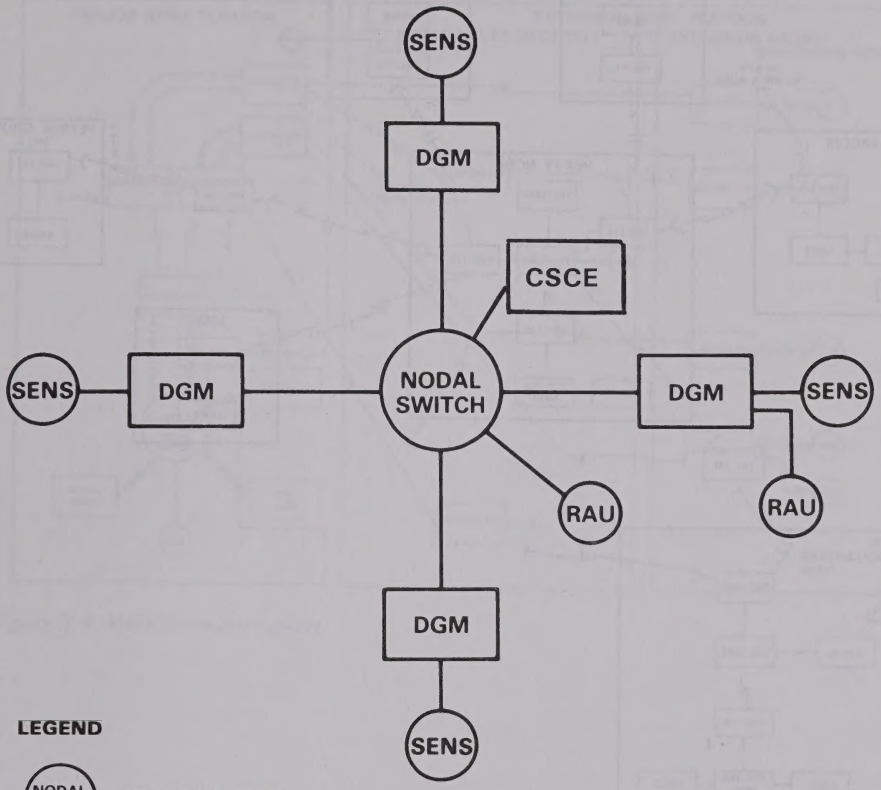
- Subscribers placing and receiving calls using standard telephone procedures without knowing network connectivity, operating frequency, or location of called subscriber.
- The capability to operate and remain operable under climatic extremes.
- Routine precedence wire and mobile radio telephone subscribers completing a first call attempt 95 percent of the time.
- A call completion of about 15 seconds or less for tandem calls through the system from EAC boundary lines.
- System voice quality that allows for speaker recognition.
- Precedence features and class marking of circuits that permits preemption of lower precedence calls.
- Subscribers communicating traffic in the presence of enemy jamming.
- Priority subscribers communicating traffic when the system is degraded as a result of jamming.
- An automatic power level control for radio links between the area coverage functional area and the mobile subscriber access functional area.
- Automated frequency management for all friendly emitters by EAC combat units operating in the tactical area of operation.
- The capability to remote the MSRT from its RF source.
- Data conferencing for transmission of multiple addressee messages.
- Tempest levels that do not necessarily restrict supported CP's operations.
- Direct MSRT to MSRT communications without using other elements of the system.
- The ability for roving subscribers log-in as rapidly as possible on an automatic basis.
- The ability to restrict subscriber access.
- Call forwarding for both mobile and wire subscribers.
- Block III equipment surviving and continuing to operate when subjected to static overpressure at levels equal to that at which the operator can function.
- Thermal protection from nuclear detonations.
- Protection of equipment from EMP as a result of high altitude nuclear blast.
- System elements remaining operable at nuclear radiation levels compatible with levels established for operator personnel.

- System operators performing their tasks under MOPP IV conditions.
- Antenna configurations that minimize visual identification and detection.
- Provisions for preprogrammed and progressive voice conferencing.
- Mobile radiotelephone subscribers to reaffiliate with the area coverage equipment when encountering jamming of the primary link.
- Emitters operating in the presence of other friendly emitters.
- RF elements operating in the widest possible frequency spectrum.
- A visual or audible means of alerting the MSRT operator when contact with the Block III system cannot be accomplished.
- The ability to pass emergency plaintext information with a nonsecure warning indication when portions of the communications channel are not secure.
- The capability to install and operate the NRI device as a part of the wire subscriber access element.

The Block III system control element provides the following functions:

- Area network activation, deactivation, and reconfiguration.
- Transmission link activation and deactivation.
- Equipment status reporting.
- System connectivity display and link status.
- Automated COMSEC key management.
- Unit data base management to include demographic profile.
- Link and network load analysis.

The TRI-TAC Block III system will satisfy modern battlefield requirements for secure mobile communications and rapid displacement with system flexibility, reliability, and survivability. TRI-TAC Block III will replace the existing mix of communications equipment in the EAC area of operation. TRI-TAC Block III provides service to four major categories of subscribers: units served on an area basis; service to theater headquarters; major command support; and service to special combat organizations. (See Figures 9-2 through 9-5.)



LEGEND

NODAL SWITCH — AN/TTC-39A (MOD)

SENS — SMALL EXTENSION NODE SWITCH

DGM — AN/TRC–173

CSCE — AN/TYQ-31

RAU — RADIO ACCESS UNIT

Figure 9-2. Unit area configuration.

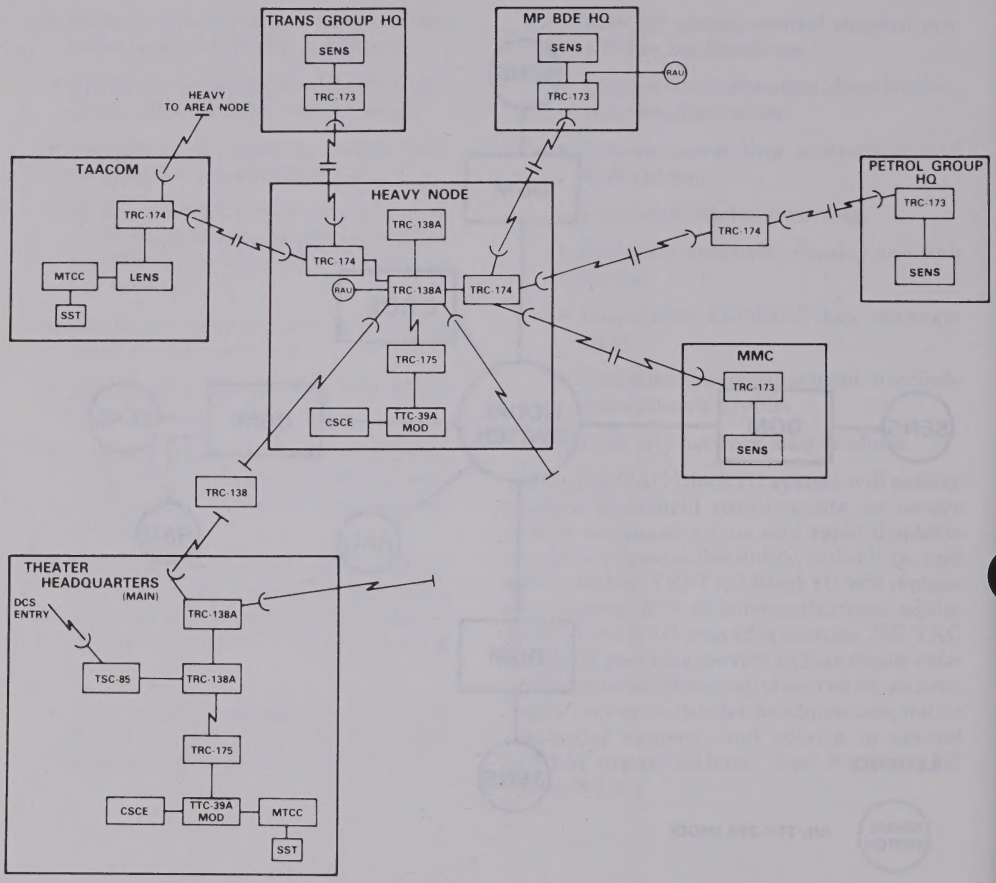


Figure 9-3. Service to theater headquarters.

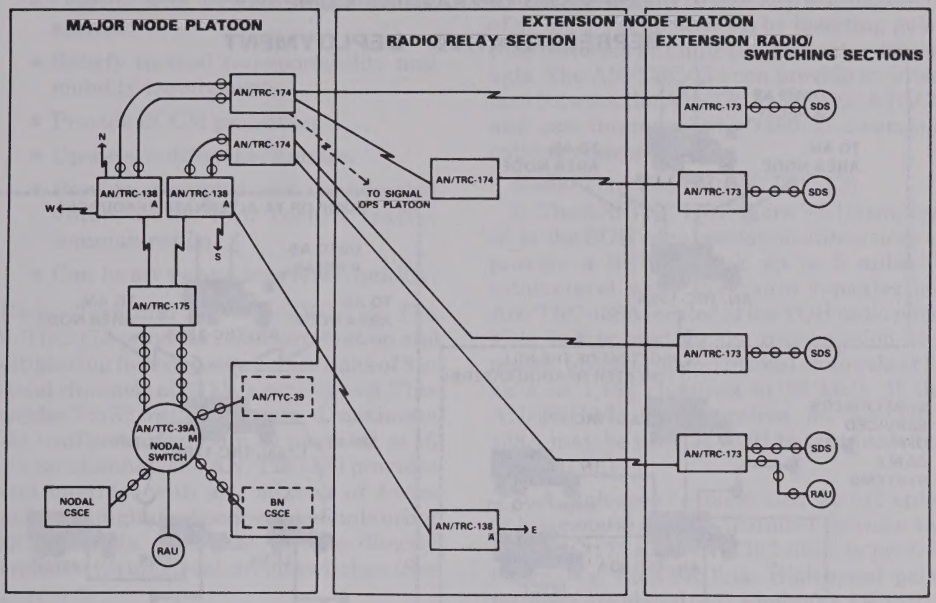


Figure 9-4. Major command support.

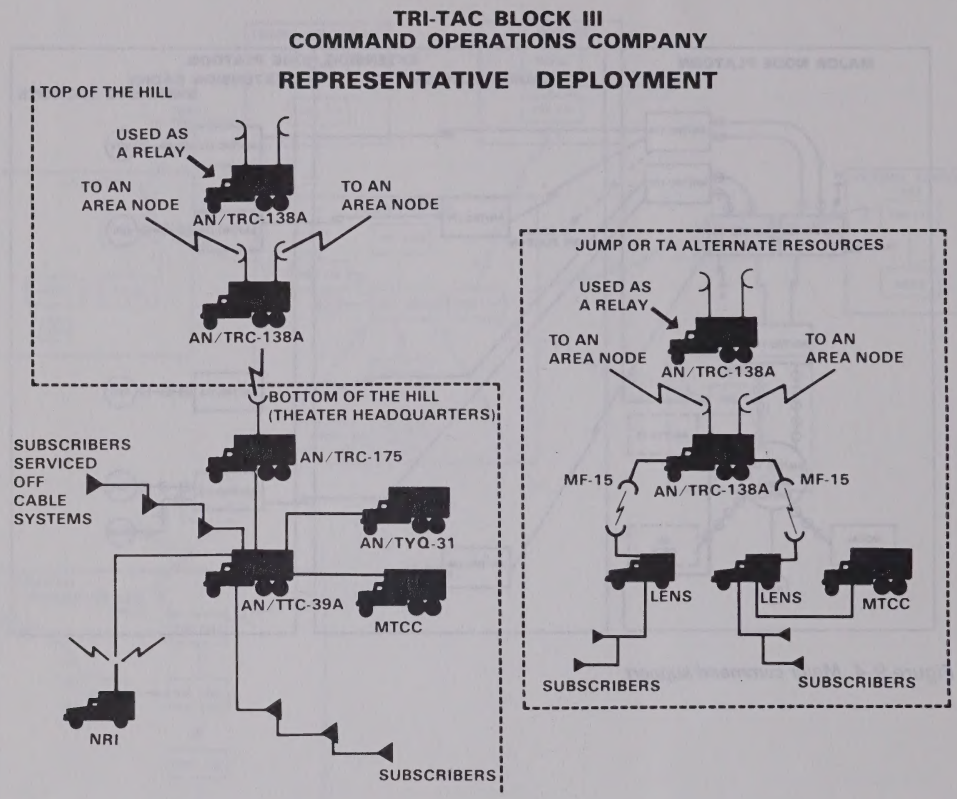


Figure 9-5. Service to special organization.

Section II. DGM and MSE Characteristics

DGM Equipment

There are four DGM assemblages as follows:

- Radio terminal set AN/TRC-173.
- Radio repeater set AN/TRC-174.
- Radio terminal set AN/TRC-175.
- Radio repeater set AN/TRC-138A.

These DGM assemblages are used in the TRI-TAC system. The DGM assemblages provide secure high capacity digital transmission facilities. Four to more than five hundred 16 kb/s to 32 kb/s channels are available by multiplexing loops into groups, by combining groups into super groups, and by combining super groups into master groups. Transmission between sites can be by radio or cable. The DGM assemblages—

- Operate 24 hours a day under battlefield conditions.

- Operate with local or remote power sources.
- Satisfy tactical transportability and mobility requirements.
- Provide ECCM protection.
- Operate in different climates.
- Provide encrypted and unencrypted voice, data, and record traffic communication.
- Can be set up and torn down quickly.

Radio Terminal Set AN/TRC-173. The AN/TRC-173 provides radio termination and multiplexing for extension access links of 8 to 36 total channels at 32 kb/s per channel. This provides 7 to 32 traffic channels. A maximum of 64 traffic channels can be provided at 16 kb/s per channel. The AN/TRC-173 provides direct interface with any mixture of 4-wire analog and digital subscriber terminals using RMCs/RLGMs. It is also used to directly interface with unit level circuit switches. (See Figure 9-6)

Radio Repeater Set AN/TRC-174.

□ The AN/TRC-174 (Figure 9-6) is employed in extension links up to 30 miles (48 kilometers) to provide users within the vicinity of the node entry into the area communications systems. It is used as a split terminal at major areas and extension nodes to provide radio termination of up to three systems of 8 to 36 channels at 32 kb/s per channel. It is also used as a radio repeater to extend the range of extension links.

□ The AN/TRC-174 is used with the AN/TRC-138A at the node or with the large or small extension switch at extension nodes for split terminal applications. The AN/TRC-174 does not have a trunk encryption capability. All trunk groups must first be encrypted at the extension switch or AN/TRC-173 before transmission over a radio link employing the AN/TRC-174. The AN/TRC-174 may also be used to terminate low speed cable systems. These systems may be extended to a maximum of 40 miles (64 kilometers) by inserting pulse code restorers at 1 mile (1.6 kilometers) intervals. The AN/TRC-174 can provide an interface between the AN/TRC-138A and ATACS and can improve army tactical communications systems.

Radio Terminal Set AN/TRC-175.

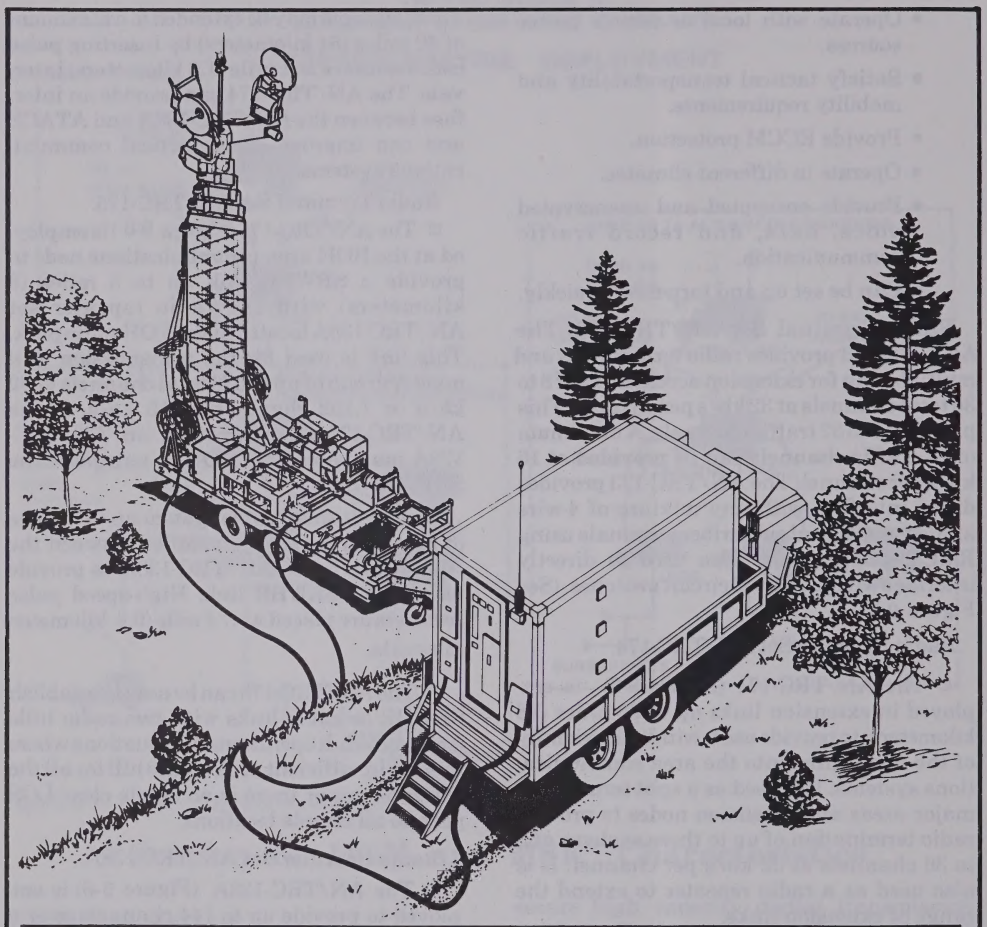
□ The AN/TRC-175 (Figure 9-6) is employed at the BOH area communications node to provide a SRWBR link up to 5 miles (8 kilometers) with the radio repeater set AN/TRC-138A located at the TOH radio park. This link is used for the transmission of a master group of up to 576 total channels at 32 kb/s or 1,152 channels at 16 kb/s. If the AN/TRC-175 is inoperative, an AN/TRC-138A may be used at BOH to terminate the SRWBR link.

□ A high-speed cable system up to 5 miles (8 kilometers) may be installed between the AN/TRC-175 and AN/TRC-138A to provide backup for SRWBR link. High-speed pulse restorers are placed at 1/4-mile (0.4 kilometer) intervals.

□ The AN/TRC-175 can be used to establish SRWBR or cable links with two radio hills (split radio hill operations) in situations where there is insufficient area on one hill for all the assemblages or there is no single clear LOS path to all remote locations.

Radio Repeater Set AN/TRC-138A.

□ The AN/TRC-138A (Figure 9-6) is employed to provide up to 144 channels over a microwave link with adjacent nodes and for SRWBRs and high-speed cable links between the BOH area communications node and the TOH radio park. It is used as a radio/cable terminal to terminate up to three systems or as a radio repeater to extend the range of internodal multichannel links. The AN/TRC-138A is used in both PCM (12 to 96 channels) and DGM (36 to 144 channels) multichannel systems to satisfy operational requirements.



EQUIPMENT	TYPE SHELTER	TYPE ANTENNA/MAST	VEHICLE
AN/TRC-173	S-589	AS-3047/AB-577 or AB-1309	5-TON
AN/TRC-174	S-590	AS-3047/AB-577 or AB-1309	5-TON
AN/TRC-175	S-591	AS-1425/AB-621 or AB-1309	5-TON
AN/TRC-138A	S-667	AS-1425/AB-621 or AB-1309	5-TON

Figure 9-6. Radio assemblages.

□ This assemblage is the foca
radio park and has the respons
tributing the radio multichanne
exiting the radio park. Addit
AN/TRC-138A is used to provide
and consolidation of equipme
circuits between the BOH area
tions node and the TOH radio
channel assemblages.

Mobile Subscriber Equi

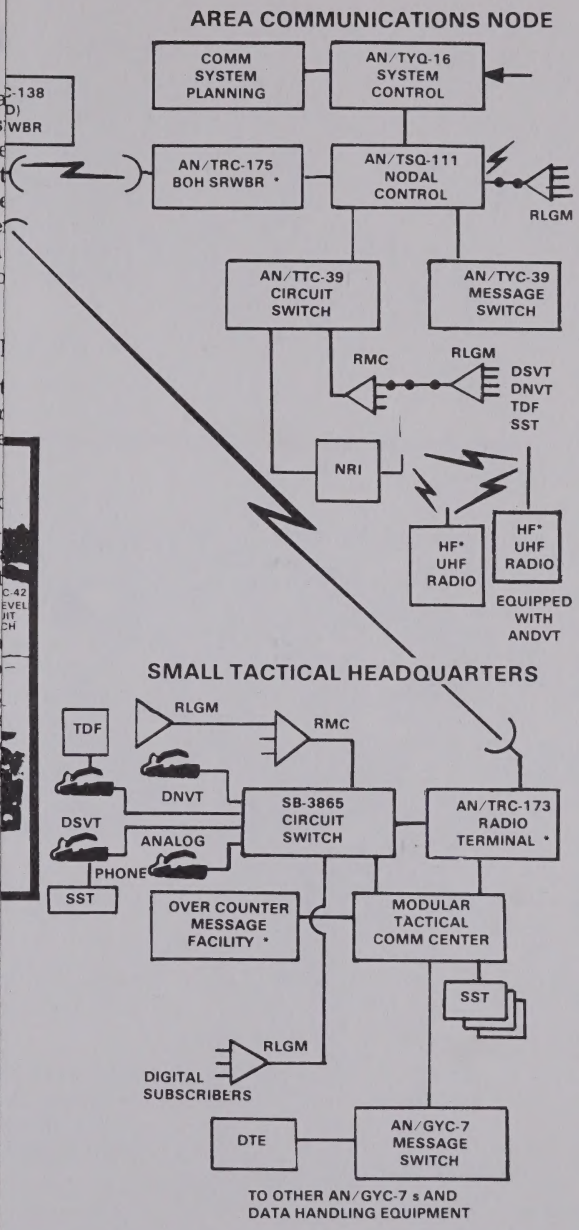
MSE provides an interface be
and fixed subscribers. (See Figur
equipment is used in many place
system.

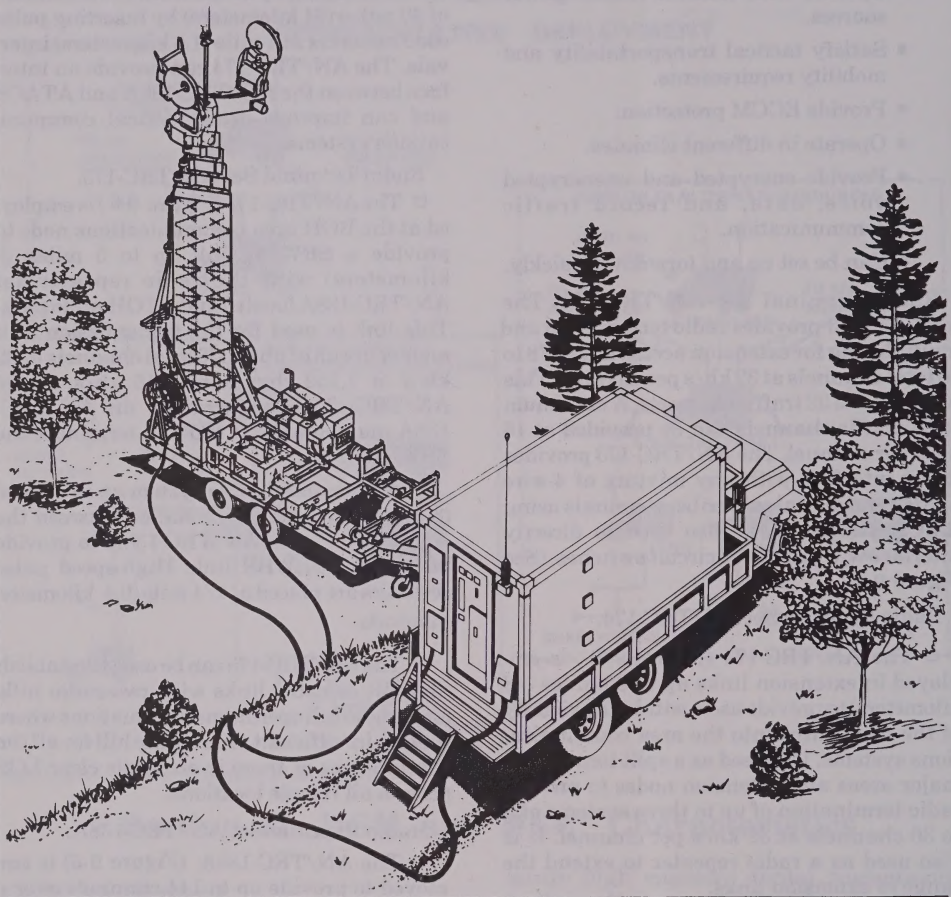
An AN/TCC-39A circuit switc
of software, cannot directly cal
ever, an AN/TTC-39A can c
subscriber switch which format
for MSE use.

The AN/TRC-173, 174, 175, a
carry MSE channels and group
AN/TRC-174, 175, and 138A, g
used to carry the MSE informa
the AN/TRC-173, only the gr
interface with MSE system. T
not use TGM super groups. RL
channels can interface with MS
fixed sites.

The LENS is a mobile, si
microprocessor-based, modular
integral COMSEC and multip
ment. It can provide switching
digital channels. The LENS wi
GM in the AN/TRC-173 shelter
cable is part of the MSE syste

A 30-line SENS (AN/TTC-48
provide communications supp
units. It connects the GM or
within the AN/TRC-173 via C
and is part of the MSE system.





EQUIPMENT	TYPE SHELTER	TYPE ANTENNA/MAST	VEHICLE
AN/TRC-173	S-589	AS-3047/AB-577 or AB-1309	5-TON
AN/TRC-174	S-590	AS-3047/AB-577 or AB-1309	5-TON
AN/TRC-175	S-591	AS-1425/AB-621 or AB-1309	5-TON
AN/TRC-138A	S-667	AS-1425/AB-621 or AB-1309	5-TON

Figure 9-6. Radio assemblages.

□ This assemblage is the focal point of the radio park and has the responsibility of distributing the radio multichannel entering or exiting the radio park. Additionally, the AN/TRC-138A is used to provide distribution and consolidation of equipment orderwire circuits between the BOH area communications node and the TOH radio park multichannel assemblages.

Mobile Subscriber Equipment

MSE provides an interface between mobile and fixed subscribers. (See Figure 9-7 .) DGM equipment is used in many places in the MSE system.

An AN/TCC-39A circuit switch due to lack of software, cannot directly call MSE. However, an AN/TTC-39A can call a mobile subscriber switch which formats the signals for MSE use.

The AN/TRC-173, 174, 175, and 138A can carry MSE channels and groups. Within the AN/TRC-174, 175, and 138A, groups can be used to carry the MSE information. Within the AN/TRC-173, only the group side can interface with MSE system. The MSE does not use TGM super groups. RLGM and RMC channels can interface with MSE channels at fixed sites.

The LENS is a mobile, single shelter, microprocessor-based, modular switch with integral COMSEC and multiplexing equipment. It can provide switching for up to 150 digital channels. The LENS with the digital GM in the AN/TRC-173 shelter via CX-11230 cable is part of the MSE system.

A 30-line SENS (AN/TTC-48(V)) is used to provide communications support to smaller units. It connects the GM or RLGM/RMC within the AN/TRC-173 via CX-11230 cable and is part of the MSE system.

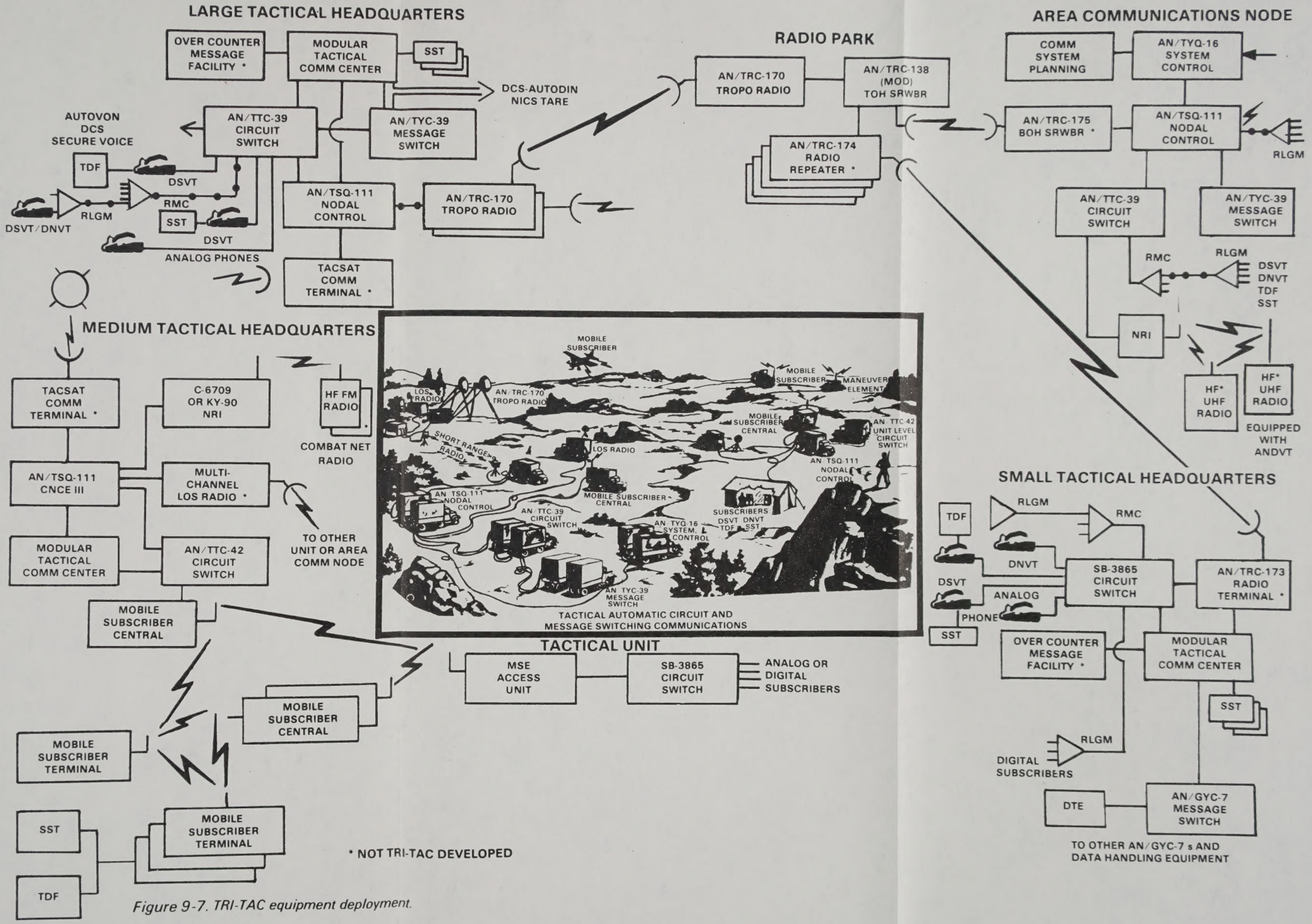
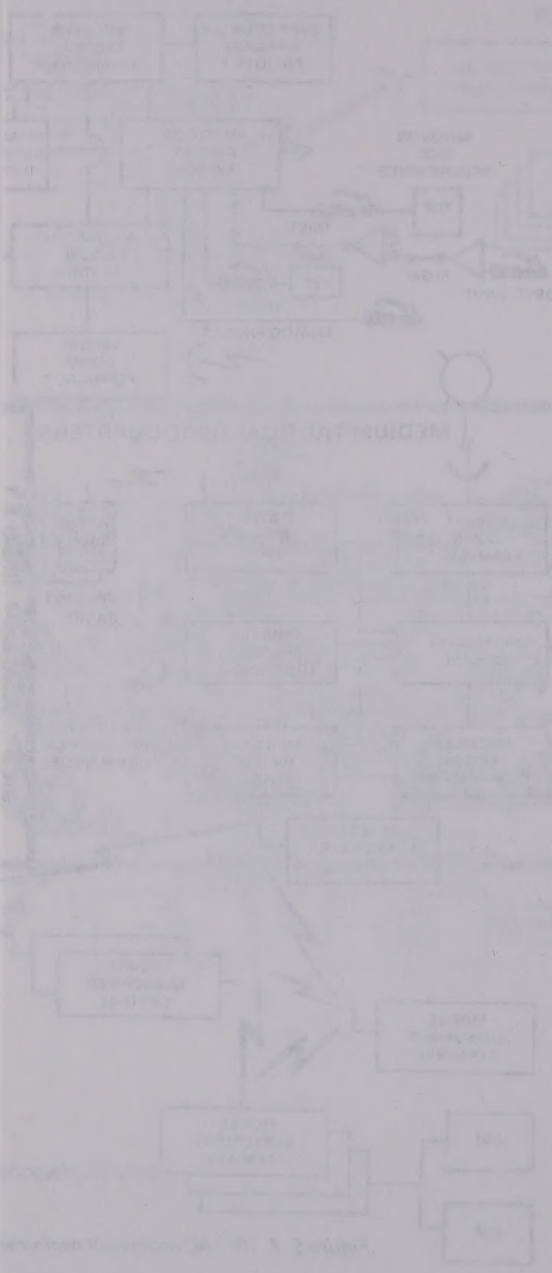


Figure 9-7. TRI-TAC equipment deployment.



Appendix A
Metric Conversion Formulas

Conversion formulas:

g to oz	g x .0353 = oz
oz to g	oz x 28.349 = g
kg to lb	kg x 2.2 = lb
lb to kg	lb x .454 = kg
MT to t	MT x 1.1023 = t
t to MT	t x .907 = MT
l to gal	1 x .2642 = gal
gal to l	gal x 3.785 = 1
cm to in	cm x .3939 = in
in to cm	in x 2.54 = cm
m to ft	m x 3.281 = ft
ft to m	ft x .3038 = m
m to yd	m x 1.0936 = yd
yd to m	yd x .9144 = m
km to mi	km x .6214 = mi
mi to km	mi x 1.6093 = km
km to naut mi	km x .540 = naut mi
naut mi to km	naut mi x 1.852 = km
mi to naut mi	mi x .8684 = naut mi
naut mi to mi	naut mi x 1.1508 = mi

NOTE: k = 1,000, therefore, 1 km = 1,000 m

1 kg = 1,000 g

Appendix B

Emergency Evacuation or Destruction of COMSEC Material

General

To guard against the possible compromise of COMSEC material when a serious threat to physical security may develop, emergency evacuation and destruction plans must be prepared. Various factors, such as the physical features of the area where the material is used, the availability of destruction material, the quantity of material to be destroyed, and the number of personnel available must be considered in plans. Provisions for the following must be included.

Emergency evacuation plans make provisions for the entry of uncleared personnel, such as firemen, into the facility and include debriefing, as necessary.

□ Assign specific responsibilities to cleared personnel by duty position rather than by name since emergencies can arise at any hour.

□ Ensure that all assigned personnel are familiar with their duties under the plan. Training exercises should be held at regular intervals to ensure that each individual has received detailed instructions on his responsibilities in an emergency.

□ Include information on the location of keys and combinations which might be required in an emergency.

□ Provide for evacuation of COMSEC information to a safe location in a systematic manner under the direction of a responsible individual. Every effort should be made to prevent loss or unauthorized viewing during the period prior to the return of the information to its original location or its relocation in a new secure area.

□ Factors which would influence the decision to evacuate the COMSEC information include the:

- Time available.
- Future requirements for the COMSEC information.
- Degree of hazard involved in the removal.
- Safety of the new location.
- Means of transportation available.
- Transportation routes available.

□ Provide for precautionary destruction, as outlined in AR 380-40, after weighing the factors above.

In the preparation of emergency destruction plans, factors used in the preparation of emergency evacuation plans will be considered. In addition, the priority of destruction of COMSEC material, as outlined in AR 380-40, will be included.

Report emergency destruction using Standard Form 153, COMSEC Material Report. This form will list the material destroyed, will be signed by the COMSEC custodian and a witness to the destruction, and will be forwarded to the office of record as soon as the situation permits.

A report of violation is forwarded immediately to the controlling authority, whether known or suspected, as outlined in Chapter 8, AR 380-40.

Glossary

Acronyms and Abbreviations

AC	alternating current
ADA	air defense artillery
AJCM	antijam control modem
altn	alternate
AM	amplitude modulated
AMCL	aperture to medium coupling loss
ANDVT	advanced narrowband digital voice terminal
approx	approximately
AR	Army regulation
arty	artillery
ASC	Army Signal Center
ATACS	Army Tactical Communications System
ATE	automatic test equipment
AUTODIN	automatic digital network
AUTOSEVOCOM	automatic secure voice communications
AUTOVON	automatic voice network
AVIM	aviation intermediate maintenance
avn	aviation
AVUM	aviation unit maintenance
AWG	American wire gage
BDAR	battle damage assessment repair
bde	brigade
bn	battalion
BOH	bottom of hill
BPF	band pass filter
C(AA)B	Combat (Air Artillery) Brigade
cbl	cable
CBRE	chemical, biological, radiological element
CCN	Corps Communications Network
CDR	commander

cen	center
CEWI	combat electronic warfare intelligence
ch	channel
cm	centimeter
CNCE	communications nodal control element
CO	commanding officer
coax	coaxial
COMINT	communications intelligence
comm	communications
COMMZ	communications zone
COMSEC	communications security
CONUS	continental United States
CP	command post
CRL	circuit routing list
CSCE	communications systems control element
CSPE	communications system planning element
CU	common user
D/I	drop and insert
DA	Department of the Army
DARCOM	United States Army Materiel Development and Readiness Command
db	decibel
dbm	decibels above (or below) one millowatt
DCA	Defense Communications Agency
DCS	Defense Communications System
DCSC	division command signal center
DCSS	Digital Communications Subsystem
deg	degree
demod	demodulate
DGM	digital group multiplexer
DISCOM	division support command
DISSC	division support signal center

div	division
DIVARTY	division artillery
DNVT	digital nonsecure voice terminal
DOD	Department of Defense
DS	direct support
DSCS	Defense Satellite Communications System
DSVT	digital subscriber voice terminal
DT	development testing
DTAC	division tactical command post
DTE	data terminal equipment
DTOC	division tactical operations center
DX	direct exchange
EAC	echelons above corps
EAD	echelons above division
ECCM	electronic counter-countermeasures
ECM	electronic countermeasures
EHF	extra high frequency
elev	elevation
EMI	electromagnetic interference
EMP	electromagnetic pulse
engr	engineers
ETP	estimated transmit power
EW	electronic warfare
FA	field artillery
FAA	Federal Aviation Administration
FASC	forward area signal center
fax	facsimile
FC	field circular
FCC	Federal Communications Commission
FEBA	forward edge of the battle area
FLOT	forward line of own troops

FM	frequency modulated/field manual
FOTS (LH)	fiber optic transmission (long haul)
FSB	fire support base
ft	feet
FW	field wire
fwd	forward
g	gram
gal	gallon
GHz	gigahertz
GM	group modem
GMF	ground mobile forces
GS	general support
G2	Assistant Chief of Staff, G2 (Intelligence)
G3	Assistant Chief of Staff, G3 (Operations and Plans)
HF	high frequency
HO	height obstacle
HQ	headquarters
HSPR	high-speed pulse restorer
Hz	hertz
IATACS	Improved Army Tactical Communications System
IAW	in accordance with
IDS	intermediate direct support
IGS	intermediate general support
in	inch
INTACS	Integrated Tactical Communications Systems
IRAC	Interdepartment Radio Advisory Committee
ITU	International Telecommunications Union
JCS	Joint Chiefs of Staff
J/FP	joint frequency panel

k	kilo
kb/s	kilobits per second
kg	kilogram
kHz	kilohertz
km	kilometer(s)
kw	kilowatt(s)
l	liter
lb	pound(s)
LB	Basic Loss
LENS	large extension node switch
LH	long haul
LL	long local
LOI	letter of instruction
LOS	line-of-sight
LSPR	low-speed pulse restorer
m	meter
MAC	maintenance allocation chart
MCEB	Military Communications-Electronics Board
mchan	multichannel
MCP	maintenance collecting point
METT-T	mission, enemy, terrain, troops and time available
MHz	megahertz
mi	mile
MI	military intelligence
MMC	Materiel Management Center
mod	modified
MOPP	mission-oriented protection posture
MP	military police
MR	major relay
MSC	midscale

MSD	multichannel system designator
MSE	mobile subscriber equipment
MSRT	mobile subscriber radiotelephone terminal
MST	maintenance support team
MT	metric ton
MTCC	modular tactical communications center
mux	multiplex
MWO	modification work order
NATO	North Atlantic Treaty Organization
naut mi	nautical mile
NBC	nuclear, biological, chemical
NICS	NATO Integrated Communications System
NRI	net radio interface
OCU	orderwire control unit
OMT	orth mode transducer
OPORD	operation order
ops	operations
ORF	operational readiness float
org	organization
oz	ounce
PAM	pulse amplitude modulation
PCM	pulse code modulation
petrol	petroleum
PMCS	preventive maintenance checks and services
PR	priority
pr	pair
preamp	preamplifier
QEEM	quick erect expendable mast
QRA	quick raise antenna
R	receiver
RAOC	rear area operations center

RAU	radio access unit
rdo	radio
rec	receive
RF	radio frequency
RLGM	remote loop group modem
RMC	remote multiplexer combiner
RSL	receive signal level
RWI	radio wire integration
SASP	special ammunition supply point
SATCOM	satellite communication(s)
SC	special category
SCC	system control center
SCT	single channel transponder
SDNRI	secure digital net radio interface
SDS	software development station
SENS	small extension node switch
SHF	super high frequency
sig	signal
SMDR	Structure Manning Decision Review
S/N	signal to noise
SOI	signal operating instruction
SOP	standing operating procedure
spt	support
SRWBR	short range wideband radio
SST	single subscriber terminal
STU	secure telephone unit
SU	sole user
sw	switch
swb	switchboard
sys	system
SYSCON	systems control

S2	Intelligence Officer (US Army)
S3	Operations and Training Officer (US Army)
t	ton
T	transmitter
TA	Theater Army
TAACOM	Theater Army Area Command
TACP	tactical command post
TACSAT	tactical satellite
TACSATCOM	tactical satellite communications
TADS	tactical automatic digital switch
TB	technical bulletin
TCC	telecommunications center
TCP	traffic control point
TDA	tables of distribution and allowances
TDF	tactical digital facsimile
TDM	time division multiplex
TECHCON	technical control
TED	trunk encryption device
TGM	trunk group multiplexer
TM	technical manual
tml	terminal
TOE	table(s) of organization and equipment
TOH	top of hill
tp	telephone
TRADOC	United States Army Training and Doctrine Command
TRI-TAC	Tri-Service Tactical Communications
tropo	troposphere
tt	teletypewriter
TWT	traveling wave tube

TWTA	traveling wave tube amplifier
ty	type
UHF	ultra high frequency
UMCP	unit maintenance collecting point
US	United States
V	volts
VF	voice frequency
VHF	very high frequency
WR	wire receive
WS	wire send
WT	wire transmit
2W	two wire
4W	four wire
xmit	transmit
yd	yard

Definitions

ABM PLAN - Method of frequency assignment.

ANALOG - The representation of numerical quantities by physical variables such as translation, rotation, voltage, and resistance.

APEX - Tip, point, or vertex; summit.

ATTENUATION - Decreasing amplitude of an electric signal.

AUTHENTICATION - A security measure designed to protect a communications system against acceptance of a fraudulent transmission or simulation by establishing the validity of a transmission, message, or originator.

AZIMUTH - Direction plotted on a map, from one point to another.

BLOBS - Tropospheric turbulence clouds.

BOOBYTRAP - Camouflaged antipersonnel weapon or device.

CLAYMORE MINE - Antipersonnel explosive device.

CLEAR TEXT - Transmitting unsecure traffic or data.

COSMIC INTERFERENCE - Interference caused by phenomenon outside the earth's atmosphere.

CROSS POLARIZATION - The component of the electric field vector normal to the desired polarization component.

DIPOLE - Antenna element.

ELLIPSOIDAL REGION - Area within Fresnel zone.

ENCRYPTED - Coded data.

FRESNEL ZONE - A conical zone that exists between microwave transmitting and receiving antennas.

GEOSTATIONARY SATELLITE - A satellite in a stationary or synchronous orbit with respect to the earth.

GHz - One billion cycles per second.

GRID COORDINATES - Numbers describing specific locations on a military map.

IDLE NOISE - Noise generated by mixer diodes, low level amplifiers, and other circuitry.

IONOSPHERE - The region of earth's atmosphere, 50 to 250 miles above the earth's surface.

JUMP TEAM - Radio relay team on standby to move to a new location.

JAMMING - Radiation or reradiation of electromagnetic waves to impair the usefulness of specific signals, or frequencies.

kHz - A unit of frequency that is 1000 ertz or 1,000 cycles per second.

KLYSTRON - An electron tube in which the electrons are periodically bunched by electric fields. It is used either as an oscillator or an amplifier at ultrahigh frequencies.

KNIFE-EDGE DIFFRACTION - In radio-wave propagation, an effect by which the atmospheric attenuation of a signal is reduced when the signal is diffracted as it passes over a sharp obstacle such as a mountain ridge.

LAND LINE - Multichannel Cable Carrier System.

LOS RADIO PATH - Uninterrupted electronic signal path.

MASTER STATION LOG - Record of all activity while on shift in signal assemblage.

MICROWAVE - Extremely high frequency electromagnetic wave radio.

MULTIPLEXING - Combining separate signals over a common path.

PARABOLIC ANTENNA - Concave reflector.

PATCH PANEL - Signal assemblage used to interconnect circuits by use of patch cord.

PERIMETER - Area of specific site.

PERMAFROST - Perennially frozen subsoil.

PHYSICAL SECURITY - Site integrity provided by guard personnel and defensive equipment.

POLARIZATION - Direction of radiated signal; that is, either horizontal or vertical.

PROFILE - Plotting signal paths on a map.

PROPAGATION - Transmission or dissemination of electronic signal.

REFRACTION - The change of direction of a signal in which the speed of propagation changes.

SECURE OPERATION - Transmission of encrypted signals.

SENTRY - A guard person protecting a designated area.

SKY WAVE - A radio wave propagated upward from earth.

SLING LOADED - Cargo carried by straps or nets under an aircraft (helicopter) (usually made of nylon).

SOLAR FLARE - Violent eruption of the surface of the sun.

SPACE DIVERSITY - Radio reception that involves the use of two or more antennas located several wavelengths apart, feeding individual receivers whose outputs are combined.

SUPERHETERODYNE - A receiver in which all incoming modulated RF carrier signals are converted to a common IF carrier value for additional amplification and selectivity prior to demodulation using heterodyne action.

TACTICAL - Operations under combat conditions.

TANDEM OPERATION - Two assemblages back to back.

TRIP FLARE - An illuminating device fired by wire strung across a foot path.

TROPO - Method used to transmit UHF and SHF signals.

TROPOSPHERE - Atmosphere up to approximately 10 kilometers (6 miles) in which temperature gradually decreases with altitude.

VF - 300 to 3500 Hz - (as used in communications equipment).

WAVEGUIDE - A hollow structure used to transmit radio frequency energy over limited distances, usually between the transmitter/receiver and the antenna.

References

Required Publications

Required publications are sources that users must read in order to understand or to comply with this publication.

Allied Communications Publications (ACP)

129	Communication Instructions-Visual Signaling Procedures (U)
129 (Supplement 1)	Visual Call Sign Book

Army Regulations (AR)

380-5	Department of the Army Information Security Program

Field Manuals (FM)

11-64	Communications-Electronics Fundamentals: Transmission Lines, Wave Propagation and Antennas
11-486-3	Telecommunications Engineering: Transmission and Circuit Layout
11-486-25	Microwave Transmission from 10 to 40 Gigahertz
24-16	Communications-Electronics: Operations, Orders, Records and Reports
24-18	Tactical Single-Channel Radio Communications Techniques

Related Publications

Related publications are sources of additional information. They are not required in order to understand this publication.

Allied Communications Publications (ACP)

110	Tactical Call Sign Book (U)
121	(C) Communication Instructions - General (U)
121(B)-1 (C-NOFORN)	(C) Communication Instructions - General (U)
122	(C) Communication Instructions - Security (U)
124	(C) Communication Instruction - Radiotelegraph Procedures (U)
125(D)	Communication Instructions - Radiotelephone Procedures (U)
126	(R) Communication Instructions - Teletypewriter (Teleprinter) Procedures (U)
131	Communication Instructions - Operating - Signals (U)

Army Regulations (AR)

105-31	Record Communications
310-25	Dictionary of United States Army Terms
310-50	Authorized Abbreviations and Brevity Codes
380-40	(C) Policy for Safeguarding and Controlling COMSEC Information (U)
380-53	Communications Security Monitoring
380-150	Access to and Dissemination of Restricted Data
530-2	Communications Security
530-3	(C) Electronic Security (U)
530-4	(C) Control of Compromising Emanations (U)
604-5	Personnel Security Program
700-18	Provisioning of US Army Equipment

Department of Army Pamphlets (DA PAM)

25-30	Consolidated Index of Army Publications and Blank Forms
108-4	Index of Army Motion Pictures for Public Nonprofit Use
738-750	The Army Maintenance Management System (TAMMS)
750-1	Organizational Maintenance Guide for Leaders

Field Manuals (FM)

5-20	Camouflage
5-30	Engineer Intelligence
11-28	Signal Command Operations Battalion (Theater)
11-50	Combat Communications Within the Division (How to Fight)
11-92(HTF)	Combat Communications Within the Corps (How to Fight)
19-30	Physical Security
21-11	First Aid for Soldiers
21-26	Map Reading and Land Navigation
21-31	Topographic Symbols
21-76	Survival
24-1	Combat Communications

24-2	Radio Frequency Management
24-17	Tactical Communications Center Operations
24-20	Tactical Wire and Cable Techniques
24-22	Communications-Electronics Management Systems (CEMS)
31-70	Basic Cold Weather Manual
31-71	Northern Operations
32-20	(C) Electronic Warfare (EW) (U)
34-62	Counter-Signals Intelligence (C-SIGINT) Operations
44-8	Small Unit Self-Defense Against Air Attack
90-2(HTF)	Tactical Deception (How to Fight)
90-3(HTF)	Desert Operations (How to Fight)
90-5(HTF)	Jungle Operations (How to Fight)
90-6	Mountain Operations
90-13(HTF)	River Crossing Operations (How to Fight)
100-5	Operations
100-5-1	Operational Terms and Symbols

Forms

DA Form

2028	Recommended Changes to Publications and Blank Forms
2406	Material Condition Status Report (MCSR)
4219	4/3 Earth Profile Chart

DD Form

1753	Master Station Log (LRA)

Standard Form

153	COMSEC Material Report

Joint Army, Navy, Air Force Publications (JANAP)

201	(C) Status of Noncryptographic JANAPs and ACPs (U)

Joint Chiefs of Staff (JCS)

Pub 1	Dictionary of Military and Associated Terms

Technical Bulletins (TB)

750-25	Maintenance of Supplies and Equipment: Army Test, Measurement and Diagnostic Equipment (TMDE) Calibration and Repair Support Program

Technical Manuals (TM)

11-459	International Morse Code (Instructions)
11-486-11	Electrical Communications Systems Engineering: Definitions and Abbreviations
11-665	C-W and A-M Radio Transmitters and Receivers
11-666	Antennas and Radio Propagation
11-668	F-M Transmitters and Receivers
11-678	Fundamentals of Telephony
11-5820-595-12	Operator's and Organizational Maintenance Manual for Radio Set, AN/GRC-143
11-5895-366-14-2	Operator's Organizational, Direct Support, and General Support Maintenance Manual for Radio Terminal Sets, AN/TRC-117(V)1 and 117(V)2

Training Circulars (TC)

11-70	Communications-Electronic Fundamentals: Multiplexing

Command Publications

Command publications cannot be obtained through Armywide resupply channels. Determine availability by contacting the address shown. Field Circulars expire three years from the date of publication, unless sooner rescinded.

Field Circulars (FC)

29-2J	Unit Maintenance Operations. December 1985. Commander, US Army Ordnance Center and School, ATTN: ATSL-TD-DL, Aberdeen Proving Ground, MD 21005-5201. (FC 29-2J will be rescinded when FM 43-5 is published.)

TRADOC Pamphlets (TRADOC Pam)

525-27-3 Operational Concept for Army Maintenance System. January 1984. Commander, Headquarters, United States Training and Doctrine Command, Fort Monroe, Virginia 23651-5000

Projected Publications

Projected publications are sources of additional information that are scheduled for printing but are not yet available. Upon print, they will be distributed automatically via pinpoint distribution. They may not be obtained from the USA AG Publications Center until indexed in DA Pamphlet 25-30.

Field Manuals (FM)

43-5 Unit Maintenance Operation

Technical Manuals (TM)

11-5820-864-12 Radio Repeater Set AN/TRC-174

11-5820-865-12 Radio Terminal Set AN/TRC-173

11-5820-926-12 Operator's Organizational Manual on AN/TRC-138A Radio Terminal

11-5820-931-12 Operator's Organizational Manual on AN/TRC-175 Radio Terminal

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